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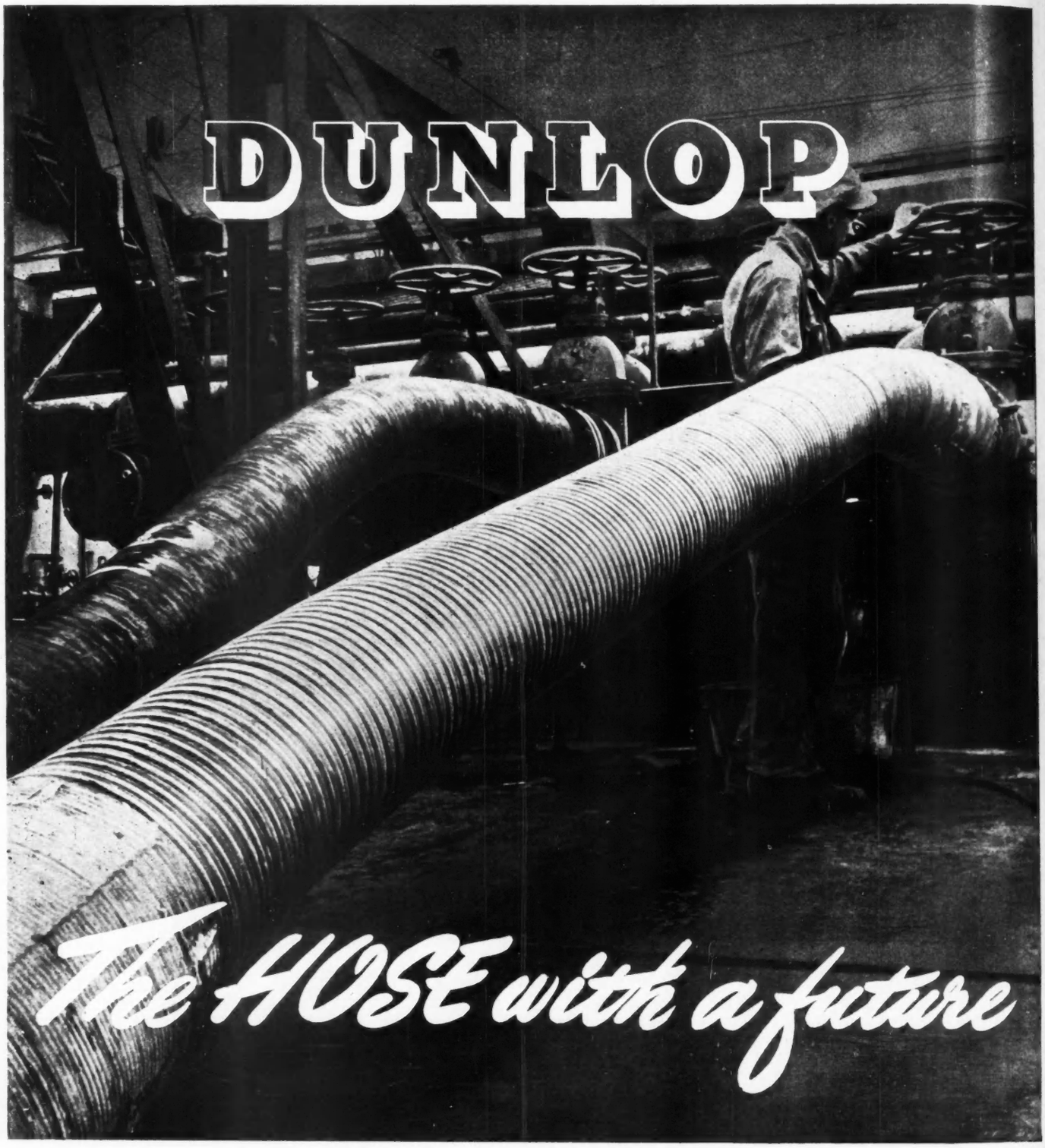


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# THE STORY OF ATOMIC ENERGY.

## II.—THE MODERN ATOMIC AND MOLECULAR THEORIES.

(*Concluded from page* 364.)

By Dr. Frederick Soddy, F.R.S.*

### The Molecular Theory.

Gay-Lussac, 1808, and Avogadro, three years later, are the true founders of the modern molecular theory, the first by the discovery of his Law of Combining Volumes, and the second for its correct interpretation by his famous Hypothesis, now elevated to the rank of a Law. The first discovered that, in general, gases chemically combine by volumes integrally related to one another and to that of their product, if gaseous. Thus, above 100 deg. C., two volumes of hydrogen unite with one of oxygen to give two volumes of steam. The second states that all gases contain, per unit of volume at the same temperature and pressure, equal numbers of molecules. Both Laws are only approximate, in that actual gases depart more and more from the gas laws the higher the pressure and the lower the temperature, the departures being the greater the nearer the conditions approach those at which the gas liquefies.

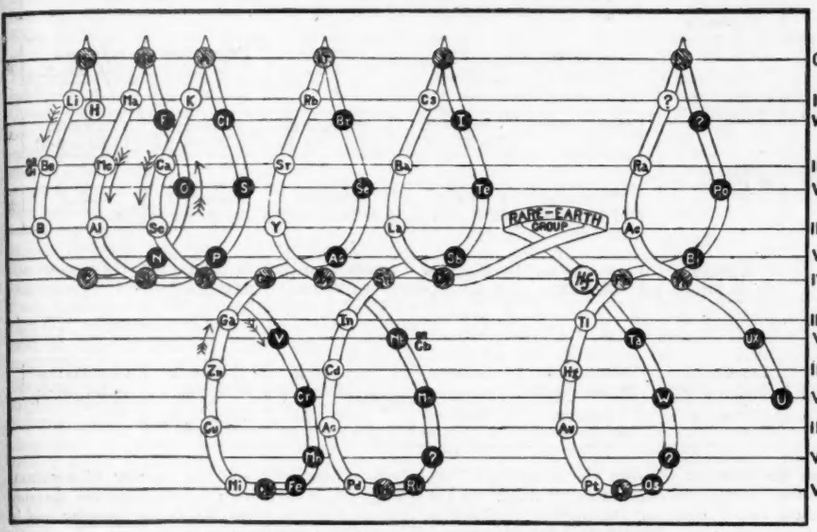


Fig. 6. Helical Representation of Periodic Law.

The two laws together show that two molecules of hydrogen unite with one molecule of oxygen to give two molecules of steam, so that, in the process, the molecule of oxygen must subdivide into two equal parts, one part going into each of the two molecules of steam formed. Oxygen is denser than steam, but not twice as dense, and the objection which Dalton foresaw from the first against equal volumes of gases having the same number of ultimate particles, does not arise if the molecules of both hydrogen and oxygen consist of two atoms and that of steam of two atoms of hydrogen and one of oxygen. But, whether because not understood, or because of the prevailing sceptical attitude towards theoretical generalisation, this simple clarification remained almost ignored at first, and was then forgotten for almost half a century, with one exception.

### The Atomic Theory of Berzelius.

Ernst von Meyer, though conventional in ascribing the foundation of the Atomic Theory to Dalton, makes it clear that it was arrived at independently by Berzelius from Richter's work on chemical equivalents, and from Davy's researches, before he was aware of Dalton's contribution. In the narrower sense now possible, as distinguishing between the Atomic and Molecular Theories, it is Berzelius who must be regarded as the founder of the present Atomic Theory.

The great Swedish pioneer of exact chemical analysis, Berzelius (1779-1848), used the Molecular Theory to correct Dalton's value for the oxygen-to-hydrogen ratio from 8 to 16, and to obtain the correct multiples of the chemical equivalents to take as their atomic weights, for the elements forming volatile compounds. To him, and not to Dalton, is to be ascribed the first table of real Atomic Weights so far as these elements are concerned. On the other hand, Berzelius was unduly tardy in recognising the validity of a great complementary generalisation, extending our knowledge to most of the rest of the elements. His first table was published in 1818, and gave values for the metals either twice or four times too great, mainly because of a curious reluctance at the time to admit such ratios as 2 : 3, 2 : 5 and 3 : 4 between the numbers of atoms of metal and oxygen in the metallic oxides.

One year later, 1819, two other generalisations were made, the first by Dulong and Petit, that the atomic heat (specific heat × atomic weight) of most of the elements is approximately the same, namely 6.

The second generalisation, discovered by Mitscherlich, is known as the Law of Isomorphism, and states that salts with the same crystalline form have similarly constituted molecules. The test of isomorphism is the ability to form mixed crystals, in which the proportion between the two salts crystallising together is infinitely variable without change of crystalline form. This discovery of isomorphism has since been extended by the microscope to the metals themselves, where the mixed crystal is termed the eutectic, and in this field, metallography, it has found a most useful application. In chemistry the most comprehensive example is the alums. These are salts with the general formula $X_2(ZO_4)_3.Y_2ZO_4.24\ H_2O$, in which X may be aluminium, iron, chromium, or other trivalent element, Y sodium, potassium or other monovalent element, and Z, a divalent element such as sulphur, selenium or tellurium. Mitscherlich's Law, when the correct atomic weight of any one of the three groups, X, Y, and Z, of analogous elements is known, makes it possible for the atomic weight of the others of that group to be inferred.

This was largely made use of by Berzelius as a guide in the compilation of his later Tables of Atomic Weights, but the first and more simple generalisation concerning the atomic heat, though ultimately to prove far the more widely applicable in this field, did not so quickly inspire confidence. It reduces the problem, what multiple of the equivalent to take as the atomic weight, to a determination of the specific heat of the element; and the law was extended by Neumann, in 1831, to simple chemical compounds also. There are, however, numerous exceptions, the explanation of which was to prove an important step in the development of the quantum theory. But these exceptions, as it happens, are in the main the non-metals of low atomic weight, of which gaseous compounds in plenty exist to which Avogadro's Law is applicable. Its value lies in being complementary to the latter and giving at once the correct atomic weights for the metals. Hence, even before the end of the second decade of last century, methods existed for ascertaining the atomic weights of practically all the elements known, though, by the middle of the century, chemists for the most part had ceased to use them, and preferred to express chemical composition in terms of the purely experimental combining ratios or equivalents. It was the growth of organic chemistry, and of its conception of the molecule as a structure—in which not only the absolute and relative numbers of atoms, but also their internal arrangement or "linkages" one to the other, is all important—that revived the chemical atomic theory.

In 1858, Avogadro's compatriot, the Italian chemist Cannizzaro, published a book, systematising all the methods of determining the atomic weights and the applicability of each, which was the means of putting the atomic theory beyond further doubt. From then on, the hiatus was rather in the determination of the molecular weights of non-volatile organic compounds, which is a necessary first step to the determination of the structure of the molecule, and that, again, must be correctly known before the substance can be artificially made, or synthesised. It was in this field that the doctrine of valency gradually developed. The atom of each element was assigned some definite number, or numbers, of units of combining power, from one to eight (in a few extreme cases), which were represented as links or bonds of union holding together the atoms in the molecule. But many elements exhibit different valencies in their different compounds. Organic compounds, being for the most part composed of carbon, hydrogen and oxygen, the valencies of which, 4, 1 and 2, respectively, are invariable, or nearly so, and of nitrogen, with valency of either 3 or 5, provided an inexhaustible field in this study of molecular architecture. This, in turn, greatly helped to put the atomic theory on a sound basis in inorganic chemistry also, though, curiously enough, in this field the actual ideas of valency that serve to cover so well the organic compounds do not apply, and the frenzied attempts to make it do so now appear like trying to force a right boot on to a left foot. However, a much more fundamental advance concerning the nature of the elements, rather than of their compounds, was to be the reward of the atomic theory, so soon as the atomic weights of a sufficiency of the elements had been established, and that was the Periodic Law.

But in historical justice, for never has the whirligig of time brought stranger revenges, a celebrated sweeping generalisation must be briefly mentioned here, which was put forward by an Edinburgh physician in 1815, and is known as Prout's hypothesis, being one of the first fruits of the Daltonian Atomic Theory. It has been universally anathematised by the historians of chemistry as constituting one of the main factors in retarding its acceptance and confusing the issues, though actually it was the inspiring mainspring that drove chemists on, in their unexciting and laborious investigations, to attempt to obtain more exact determinations of atomic weights. Doubtless from the nearly exact integral relation between the atomic weights of oxygen and hydrogen in the first instance, Prout propounded the hypothesis that all the atomic weights were integral multiples of that of hydrogen, and that the latter element was the protyle out of which matter was built up.

As, following Berzelius, the work, culminating in the 1840's, of Dumas, Marignac, and, especially, Stas, led to more and more exact determinations, it was conclusively established that the atomic weight of hydrogen, now 1·008 in terms of oxygen

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which will appear at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright; therefore no extract may be made from these articles without his permission.—Ed. E.

# THE STORY OF ATOMIC ENERGY.

## TABLE I.—PERIODIC TABLE OF THE CHEMICAL ELEMENTS, 1947.

| | GROUP 0. | GROUP I. | GROUP II. | GROUP III. | GROUP IV. | GROUP V. | GROUP VI. | GROUP VII. | |
|---|---|---|---|---|---|---|---|---|---|
| | Hydrogen 1 H 1·0080 | | | | | | | | |
| First Short Period (8) .... | Helium 2 He 4·003 | Lithium 3 Li 6·940 | Beryllium 4 Be 9·02 | Boron 5 B 10·82 | Carbon 6 C 12·010 | Nitrogen 7 N 14·008 | Oxygen 8 O 16·000 | Fluorine 9 F 19·00 | |
| Second Short Period (8) .... | Neon 10 Ne 20·18 | Sodium 11 Na 23·00 | Magnesium 12 Mg 24·32 | Aluminium 13 Al 26·97 | Silicon 14 Si 28·06 | Phosphorus 15 P 30·98 | Sulphur 16 S 32·066 | Chlorine 17 Cl 35·457 | |
| First Long Period (18) .... | Argon 18 A 39·944 | Potassium 19 K 39·096 | Calcium 20 Ca 40·08 | Scandium 21 Sc 45·10 | Titanium 22 Ti 47·90 | Vanadium 23 V 50·95 | Chromium 24 Cr 52·01 | Manganese 25 Mn 54·93 | A |
| GROUP VIII | | | | | | | | | |
| Iron 26 Fe 55·85 / Cobalt 27 Co 58·94 / Nickel 28 Ni 58·69 | Copper 29 Cu 63·54 | Zinc 30 Zn 65·38 | | Gallium 31 Ga 69·72 | Germanium 32 Ge 72·60 | Arsenic 33 As 74·91 | Selenium 34 Se 78·96 | Bromine 35 Br 79·916 | B |
| Second Long Period (18) .... | Krypton 36 Kr 83·7 | Rubidium 37 Rb 85·48 | Strontium 38 Sr 87·63 | Yttrium 39 Y 88·92 | Zirconium 40 Zr 91·22 | Niobium 41 Nb 92·91 | Molybdenum 42 Mo 95·95 | —— 43 | A |
| Ruthenium 44 Ru 101·7 / Rhodium 45 Rh 102·91 | Palladium 46 Pd 106·7 | Silver 47 Ag 107·880 | Cadmium 48 Cd 112·41 | Indium 49 In 114·76 | Tin 50 Sn 118·70 | Antimony 51 Sb 121·76 | Tellurium 52 Te 127·61 | Iodine 53 I 126·92 | B |
| Longest Period (32) .... .... | Xenon 54 X 131·3 | Caesium 55 Cs 132·01 | Barium 56 Ba 137·36 | Rare-Earths 57 to 71 | Hafnium 72 Hf 178·6 | Tantalum 73 Ta 180·88 | Tungsten 74 W 183·92 | Rhenium 75 Re 186·31 | A |
| Osmium 76 Os 190·2 / Iridium 77 Ir 193·1 | Platinum 78 Pt 195·23 | Gold 79 Au 197·2 | Mercury 80 Hg 200·61 | Thallium 81 Tl 204·39 | Lead 82 Pb 207·21 | Bismuth 83 Bi 209·00 | Polonium 84 Po 210 | —— 85 | B |
| Last Incomplete Period (7) .... | Radon 86 Rn 222 | —— 87 | Radium 88 Ra 226·05 | Actinium 89 Ac 227 | Thorium 90 Th 232·12 | Protactinium 91 Pa 231 | Uranium 92 U 238·07 | | |
| Rare-Earth Elements (15) (Taken out of the Table) | Lanthanum 57 La 136·92 | Cerium 58 Ce 140·13 | Praseodymium 59 Pr 140·92 | Neodymium 60 Nd 144·27 | —— 61 | Samarium 62 Sm 150·43 | Europium 63 Eu 152·0 | Gadolinium 64 Gd 156·9 | |
| | Terbium 65 Tb 159·2 | Dysprosium 66 Dy 162·46 | Holmium 67 Ho 164·94 | Erbium 68 Er 167·2 | Thulium 69 Tm 169·4 | Ytterbium 70 Yb 173·04 | Lutecium 71 Lu 175·0 | | |

as 16, is nearly 1 per cent. too high. Berzelius had preferred oxygen, as the basis of the atomic weights, to hydrogen for the purely practical reasons that, the latter being the lightest element, its atomic weight determination is peculiarly prone to error, and because most of the elements yield compounds with oxygen suitable for exact analysis, but very few do with hydrogen. This basis, with the atomic weight of oxygen assigned the number 16, was then found by analysts to have, however, the additional advantage that upon it, though not on hydrogen as the unit, a large number of the atomic weights were so nearly integral as to make it possible to use integers for them in ordinary work without appreciable error. This could not possibly be due to chance and it revived Prout's hypothesis in a new form. Thus it remained till the sequel, which will be dealt with when isotopes come to be discussed.

At this point the historical narrative may be interrupted with advantage in order to give as exact and succinct an account as possible of the Periodic Law as it now is, returning to tell of its actual emergence afterwards; for even now it is a sufficiently complex relationship and it is important that the reader should have in mind a correct picture of it before resuming the story.

### Periodic Classification of the Elements.

The Periodic Law resulted as the consequence of being able to arrange the chemical elements in serial order of their atomic weight, when it transpired that after a certain number, called a "period," the next period consisted of elements which were close copies, chemically, of the first. At the start of the table, the number of elements in the period was seven, which later discovery increased to eight; but after the first two periods, the next two each consist of ten more, making now 18; to the next period 14 more elements are added, making 32, and the table ends with an incomplete period of seven elements. Thus, though simple enough at the beginning of the table, in its subsequent progress the relations between the elements of the successive periods becomes more involved. In the common two-dimensional attempts to display this inter-connecting relationship, the periods are arranged horizontally, each below the previous one, in such a way that the elements in the vertical columns are chemically analogous, or "homologues," and constitute a series of "families," as they are termed, of related elements. But the progressive increase in the number in the successive periods introduces complications which cannot be avoided on any two-dimensional representation, and needs a three-dimensional figure, as was first proposed by Sir William Crookes, who arranged the elements on a spiral Figure of Eight, and regarded the Law as expressing the orderly evolution of matter from protyle. Both forms are complementary rather than alternative, each bringing out peculiar points about this complex relationship.

A Chart of the Periodic Law is printed on this page as Table I, and in Fig. 6, on page 409, the writer's representation is brought up to date. It may be again emphasised that either mode of representation is an essentially continuous sequence from No. 1 hydrogen to No. 92, uranium, which ends the natural series of elements. In the flat form, each new line of elements starts on the left, where the last line ends on the right. The particular form shown is the one best bringing out the chemical relationships. Hydrogen, in the first "place," is put outside the table proper, and being monovalent has relationship with the elements both of Group I and Group VII, but, being electropositive, more especially with the former. Though the Periodic Law was discovered by arranging the elements in order of atomic weight, by the end of last century it was realised that exceptions existed, the order of some pairs of elements being transposed. It is now known that the Periodic Law is not a relation between the chemical character of the element and its atomic weight, which is, much more often than not, merely a statistical average of several different integral atomic weights, but a relation between the chemical character and the number of negatrons (using the modern term for the negative electron) contained in the atom, which increases by one in passing from each element to the next. The periodicity of the chemical character is due to the chemically active electrons in the atom, after a certain number, reverting to zero, resulting in the family of inert gases of the atmosphere discovered in the closing years of last century, the Group Numbers 0 to VIII representing the maximum number of these active electrons in the atom. But the original relationship between chemical character and increasing atomic mass still broadly holds good in practice as an average relationship, though fundamentally wrong.

Thus, with some extensions still to be mentioned, the elements, beginning with No. 2, the first Group 0 element, helium, are classified into eight groups or families, Group I containing the strongly basic, or base-forming, alkali-metals. These are electropositive, or go to the negative electrode in the decomposition of their fused salts or solutions electrolytically, that is, by passing an electric current through the latter. At the other extreme, Group VII contains the strongly acidic, or acid-forming, electro-negative halogen elements. In passing from one group to the next, the basic character gradually weakens, Group II containing the still very strongly basic alkaline-earth elements, hardly less basic than the alkali elements of Group I. At the middle of the table, Group IV, at carbon in the first period, electro-neutrality is reached, and after that, to Group VII, the families become increasingly acidic.

The maximum valency of the element is its group number when acting as an electro-positive or basic element, and eight minus its group number, when acting as an electro-negative element, a generalisation known as Abegg's Rule. It may be said that the strongly contrasted character of the groups at the beginning and end of the successive periods makes the chemistry of these elements usually much simpler and more definite than those in the

middle, especially for the heavier members, the chemistry of which is sometimes very incalculable. In modern terms, the compounds of the first are usually "polar" and of the second frequently "non-polar," and the clearer distinction between them now possible has done much to facilitate the chemistry of the elements in the middle of the Periodic Table. Especially for the heavier members in the middle of the table, a marked increase of basic character occurs with increasing atomic weight, in passing down the vertical columns. Also, although the elements of the first short period were called by Mendelejeff and are still known as the "typical elements," they are usually less typical of the chemical character of their families than those of the second period.

Coming now to the complication introduced by the increased number of elements in the later periods, these are best regarded as occurring through the interpolation into the original periods of a succession of ten elements, all metals, between Groups II and III, as indicated on the chart by breaking the horizontal lines. After the first two Short Periods, which contain the first two members of the eight groups or families, there are two Long Periods, each of 18 elements. Of the ten elements interpolated, the first five and last two fall in the Groups III to VII and I and II, respectively, leaving what is called Group VIII, which is a sequence of three very similar metals, under the elements in Group O. So that so far as the latter group is concerned, after the third element, argon, the analogy continues with the alternate, not successive, members in the vertical column, and is dual, between inert gases on the one hand and the Group VIII elements on the other. But at the beginning and the end, in Groups III and II, respectively, although this also is true, there is considerable chemical resemblance between the successive vertical members as well, gradually weakening in the other groups as Group VIII is approached in either direction. This is largely because Abegg's Rule applies, though not so sharply, to the interpolated members also, making the compounds of the elements in the same vertical column of the same general type. Historically, the Long Periods were divided into the two sub-periods, called A, for the first eight, and B for the last seven, with the three Group VIII elements between, as indicated on the chart.

In the next or Longest Period, 14 more elements, called the Rare-Earth Elements, all trivalent and extremely close copies of the first, lanthanum in Group III, have been interpolated, and the latter and these, 15 in all, have been taken out of the chart and shown separately below for convenience and compactness. In the last Incomplete Period of seven members, the course thus far follows that of the two Long Periods, not of the Longest Period immediately preceding. This has been known for long to indicate a fresh departure in the periodicity, which is now being cleared up in an interesting manner and is discussed later, where the new transuranic elements are dealt with.

### The Spiral Form of the Periodic Law.

With regard to the spiral arrangement, shown in Fig. 6, this attempts a diagrammatic representation of the points above discussed. The electro-positive elements, shown in black letters on a white ground, are to be regarded as above, and the electro-negative, white letters on black ground, as below the plane of the paper, and the interpolated elements, as the lower halves of three successive figures of eight, those in the plane of the paper, as black letters on sectioned ground; the interpolated rare-earth elements are shown by a loop.

The pointed tops of the upper parts of the figures of eight, and the almost flat bases of the lower parts, are intended to represent the extreme change of chemical character in passing from the electro-negative to the electro-positive elements on either side of the chemically inert elements, as contrasted with the great similarity of properties of the three successive elements in Group VIII. But this figure fails to bring out sufficiently the analogy between the A and B sub-periods, and is merely diagrammatic without any quantitative significance.

Having dealt with what the Periodic Law now is, we may consider briefly how it was first recognised and the effect it has had in establishing the modern atomic theory. It was discovered first in England by J. A. R. Newlands in 1864, and given by him the suggestive name of the Law of Octaves. He said: "The eighth element starting from a given one is a kind of repetition of the first, like the eighth note of the octave in music." In spite of the alteration of the period from seven to eight, his name is happily recalled by the word "octet" used in the modern chemical theory of the so-called cubic atom, for the eight electrons at the corners of a cube, which is used to represent diagrammatically the combined atom in the molecule. In the same year, a similar suggestion was made by Lothar Meyer in Germany, who together with Mendelejeff in Russia, after 1869, much extended and developed the generalisation. The latter was the first to attempt to embrace the whole of the elements in one classification, and is mainly responsible for its present form. That any connection could exist between atomic weight and chemical character was no doubt at first very astonishing to the sceptical chemist. But it is less excusable and sad to recall, that it should have been thought a fit subject for ridicule and that the original discoverer of this mighty lever to progress was denied access to the regular scientific journals of his day. Unfortunately, the increasing complexity and specialisation in science, and the degeneration of the Universities from homes of philosophy to training establishments for a new professional type of researcher in blinkers, tends to increase rather than to decrease this insufferable pharisaical attitude.

Mendelejeff, attempting to bring in all the elements, had to conclude that some places were still blank, and, in particular, he predicted the existence of three new elements, and, from their position in the table and the properties of the elements next them in the periods and groups, he indicated their chemical character sufficiently to enable them, when specially looked for, to be found at once. These he named eka-boron, eka-aluminium and eka-silicon from their lighter homologues, and they are now called scandium (1879), gallium (1875) and germanium (1887). Just before this, spectrum analysis had enriched the Periodic Table with four new elements, cæsium (1860), rubidium and thallium (1861) and indium (1863).

An even more important result was that the Periodic Law became the final court of appeal by which all remaining doubtful cases as to what multiple of the chemical equivalent represented the atomic weight, were tried, and, once the general character of the periodic system had been formulated, it became impossible for any mistake to remain uncorrected. Thus, previously, beryllium had been thought to be trivalent, with atomic weight 13·5 and indium divalent with atomic weight 75·2, but the converse is true and the atomic weights are 9 and 112·8, respectively. Uranium had been given first the atomic weight 60, later changed to 120, but the periodic law showed that the true value is 240, this last in terms of the atomic weight of hydrogen as unity. Last, and not least, it was only after the discovery of the non-valent inert gases that one could be certain that the molecules of the common gases were composed of two, and not a multiple of two, atoms. The former from their nature are necessarily monatomic, and for these gases the atom and molecule mean exactly the same thing.

At the end of last century, the chief lacunæ were, first, as to the end of the table, the elements between bismuth and thorium, Nos. 83 and 90, respectively, being missing, and only two of the last period being known. This is the region radio-activity overcrowded with some 40 radio-elements, which led to the discovery of isotopes. Secondly, there was no theoretical hint as to the number of the rare-earth elements, nor, thirdly, any certainty that the places left blank for the two homologues of manganese actually existed in the table. For sheer dogged perseverance and exactitude in experimental work, the Periodic Classification at the end of last century was a monument of achievement, all the more so in that as yet there was no hint whatever of its meaning, and from the theoretical standpoint it remained a veritable cryptogram, literally crying out to be deciphered.

## LITERATURE.

*Applied Bessel Functions.* By Professor F. E. Relton. Blackie and Son, Limited, 66, Chandos-place, London, W.C.2. [Price 17*s.* 6*d.* net.]

This book is based upon a course of lectures delivered to graduates in science and engineering, desirous of acquiring that confidence in the handling of Bessel functions that can only come from an understanding of their properties. In general, a differential equation serves to define a transcendental function, and Bessel functions are no exception. Originally developed over 100 years ago out of F. W. Bessel's investigations into the astronomical problem of the eccentric anomaly, they have been shown to occur in many branches of physics and engineering.

Professor Relton's exposition is unusual in taking the recurrence formulæ as the point of departure, but he amply justifies his adoption of it for the purpose he has in view. The first two chapters are preparatory, dealing with the error function and the beta and gamma functions, and discussing certain properties of differential equations, including the reduction of the second-order differential equation to the normal form. Much of mathematical physics is dominated by Laplace's equation and Laplace's operator, and it is shown that, when these are transformed into cylindrical co-ordinates, Bessel's equation almost inevitably appears; hence the name "cylinder function," applied to Bessel functions or combinations thereof. There are at least six different types of Bessel function, each with its own characteristic features and associated with the name of the mathematician who studied it, yet all sharing certain properties in common. The zeros and other salient features of these are located and examined in detail. Since Bessel equations often emerge in forms not readily recognisable as such at first sight, a comprehensive form of the equation is written down from which the particular instances that present themselves in practice can be derived. A number of functions are closely allied to Bessel functions. Some of these are primarily of mathematical interest. Others, such as the ber and bei functions introduced by Kelvin, are important in alternating-current theory, and these receive brief consideration. A chapter is devoted to expansions in which Bessel functions appear as coefficients; as, for example, in the Fourier series expression for the upper half of a circle. Certain purely mathematical developments, such as existence theorems, are assumed without proof; for these, as Professor Relton says, are long, dull and difficult.

A representative selection of examples requiring Bessel functions for their solution is given. These include statical problems of the stability of a vertical wire, a tapered strut and a deep cantilever; dynamical problems in the motion of bodies of variable mass, the transverse vibrations of non-uniform strings and tapered rods, the normal vibration modes of membranes, and plates; hydrodynamical problems of tidal and wave motion; problems of electrical transmission along a variable line, and of heat conduction. Additional problems are covered in sets of exercises interspersed throughout the text. Though no tables are included, and little is said about numerical computation, references to such tables are given. The statement that the angle that an element of a stretched string in transverse vibration makes with the horizontal is "too small to be seen with the naked eye" is certainly too drastic, as Melde's experiment shows. Much of the spontaneity of the lecture has been preserved in the printed text, which forms an excellent introduction to Bessel functions and to their chief applications. Professor Relton is unduly modest when, in his preface, he expresses surprise at the size of the audience that followed his course, which will now prove useful to a far wider circle.

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The Story of Atomic Energy: Erratum.—An unfortunate printers' error occurred in Part II of The Story of Atomic Energy, by Dr. Frederick Soddy. In the third column of page 363, *ante*, line 4, the word "works" was inadvertently substituted for "words," making the phrase meaningless. We regret the error.

# SPEED-INCREASING GEARBOX.

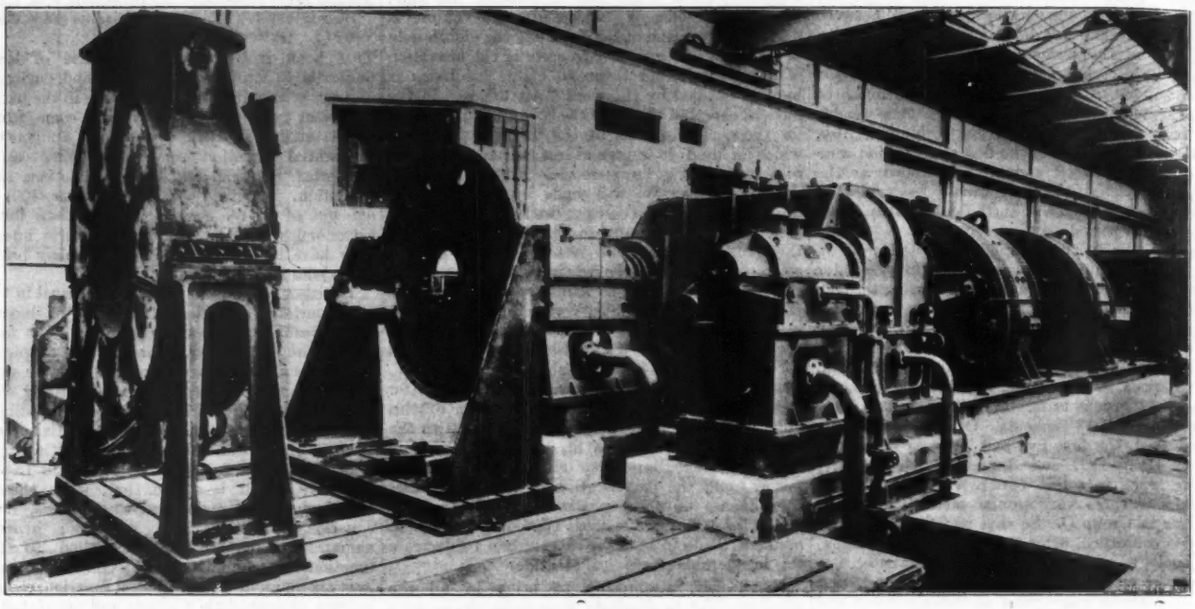


Fig. 1. General View of Test Plant.

## SPEED-INCREASING GEARBOX FOR SPECIAL TEST PLANT.

By S. A. Couling, A.M.I.C.E., A.M.I.Mech.E.

An interesting test plant consisting of a direct-current Ward-Leonard set and a speed-increasing gearbox has been constructed by the British Thomson-Houston Company, Limited, Rugby, for Messrs. Rolls-Royce Limited, for aero-engine and blower research, and has now been in service for several months. A general view of the set is shown in Fig. 1, herewith. The power requirements were 5,000 brake horse-power maximum at 13,000 r.p.m.,

Table I.—*Speeds and Loads.*

| —— | Gearbox No. 1. | Gearbox No. 2. | Gearbox No. 3. |
|---|---|---|---|
| Number of teeth .. | 39/392 | 29/48 | 23/54 |
| Ratio .. .. .. | 10·04 | 1·654 | 2·35 |
| Speed range, r.p.m. .. | 800/8,000 | 8,000/13,000 | 8,000/18,500 |
| Centres, in. .. .. | 39·577 | 7·07 | 7·07 |
| Pinion pitch-circle diameter, in. .. .. | 7·1624 | 5·3259 | 4·224 |
| Pitch-line velocity (ft. per second) .. | 250 | 303 | 342 |
| Face width, in. .. | 2 by 10 | 2 by 7 | 2 by 6 |
| Loading (lb. per inch) | 550 | 651 | 402 |
| Tooth stress (lb. per square inch) .. | 7,200 | 9,120 | 6,040 |
| Bearing load, lb. .. | 6,100 | 4,915 | 2,615 |
| Bearing size, in. .. | 5 by 9 | 3½ by 7 | 2½ by 5 |
| Bearing loading (lb. per square inch) .. | 135·5 | 201 | 190 |
| Bearing velocity (ft. per second) .. | 175 | 199 | 221 |

and a maximum of 3,000 brake horse-power at 18,500 r.p.m. Power was also required at all speeds down to 6,000 r.p.m.; the curve of output, from the maximum downwards, was assumed to be that of a fan charsoteristic. Two direct-current motors in tandem, having a speed range of 800 r.p.m. to 350 r.p.m., are coupled to the low-speed shaft of the gearbox through a spring-type flexible coupling. Two pinions, driven by the low-speed gearwheel and each increasing the speed from 800 r.p.m. to 8,000 r.p.m., are connected through gear-type flexible couplings to two auxiliary gearboxes, which raise the speed further, from 8,000 r.p.m. to 18,500 r.p.m., in one case, and 8,000 r.p.m. to 13,000 r.p.m. in the other.

The velocities and loadings, up to maximum speed and power, are given in Table I, and the diagrams, Figs. 2 and 3, opposite for the pinion

Table II.—Comparative Losses for Individual Gearbox Bearings.

| No. of Bearings. | Diameter and Length, in.; and Speed, r.p.m. | Reference to Curves in Fig. 7. 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|---|
| 2 | 8 by 12 (800) | 9·88 $C = 0·00112$ $p = 112$ | 1·35 | 6·08 | 5·64 | 5·04 | 4·69 |
| 4 | 5 by 9 (8,000) | 838·4 $C = 0·0012$ $p = 136$ | 184·0 | 152·4 | 136·2 | 106·0 | 75·2 |
| 2 | 3 by 7 (8,000) | 81·0 $C = 0·00215$ $p = 210$ | 27·4 | 45·0 | 31·0 | 16·0 | 11·5 |
| 2 | 2½ by 5 (18,500) | 84·0 $C = 0·00346$ $p = 190$ | 84·0 $\Delta t = 30$ deg. F. | 63·0 | 49·4 | 24·4 $t_1 = 100$ deg. F. | 24·2 |
| Total loss, b.h.p. | | 1,013 | 297 | 267 | 222 | 152 | 116 |

teeth and bearings. The loadings of both teeth and bearings for No. 1 box call for no particular comment; the details of design follow normal established practice. The pinions are of nickel-chrome steel and the wheels of 0·04 per cent. carbon steel, having ultimate tensile strengths of 50 tons and 40 tons per square inch, respectively. Oil is supplied from a motor-driven gear-type pump to a manifold in the gearbox and from there is fed to the tooth sprayers and the bearing oil-ways. Each of the bearings has a distant-reading thermometer recording the temperature of the whitemetal in the loaded half bearing. A Klaxon horn connected to these thermometers gives warning if the temperature reaches a predetermined limit. The main pinions are mounted well above the horizontal centre-line of the main gearwheel, so that, with either direction of rotation and with either of the pinions loaded, the wheel is always on the bottom halves of its bearings. This ensures stability of running and avoids the condition in which, in one direction of rotation, the tooth reaction may overcome the gravitational weight of the slow-speed wheel and lift the shaft off the bottom of the bearings.

Difficulties became apparent when considering boxes No. 2 and No. 3. A compromise had to be made in the pinion design between pitch-line speed and tooth loading to keep the former at a reasonable limit and to avoid a combined bending and torsional deflection of not more than 0·001 in. This resulted in a tooth-loading coefficient higher than is used in general practice. Fig. 4, opposite, shows the rolling and sliding speeds for the 18,500 r.p.m. pinion, and it will be noted that the tooth sliding velocities are three to four times the normal practice. Addendum and tip relief were adjusted to ameliorate the conditions as far as possible. In addition, following consultation with an oil company, a special extreme-pressure oil was selected for lubrication and cooling.

Although the particulars of tooth design are for loading of a high order, the bearings are, perhaps, more interesting. The tooth reactions were equivalent to 4½ tons to be supported at 13,000 r.p.m. and 2¾ tons at 18,500 r.p.m. A compromise had to be made between peripheral velocity and specific loading on the bearings. It is possible to reduce the latter by an increase of length of bearing, but the use of an over-long bearing is always questionable because of the deflection of the shaft within the bearing length. As shown, 3½ in. by 7 in. bearings were used for the 13,000-r.p.m. shaft, and 2½ in. by 5 in. for the 18,500-r.p.m. shaft; even then, both loadings and speed were higher than is customary.

The bearing oil passages and general design are illustrated in Figs. 5 and 6, opposite. It will be noted that the bearings have very thin white-metal linings, only 0·020-in. thick, and cast into steel shells without any dovetails or locking devices. From tests, it had been shown that thin Babbitt and steel shells gave much better adhesion between the whitemetal and the shell than the conventional cast-iron shell with dovetails and the usual white-metal thickness of about $\frac{1}{8}$ in. Furthermore, with

# SPEED-INCREASING GEARBOX.

Fig. 2.

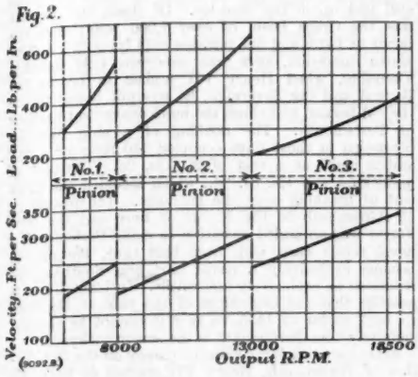



Fig. 3.

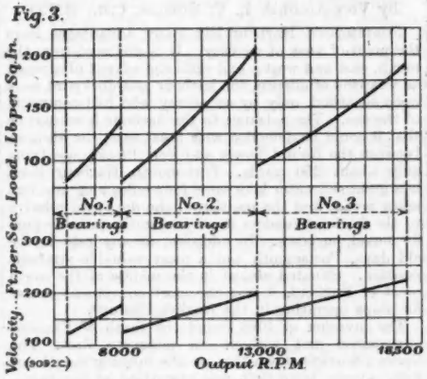



Fig. 4.

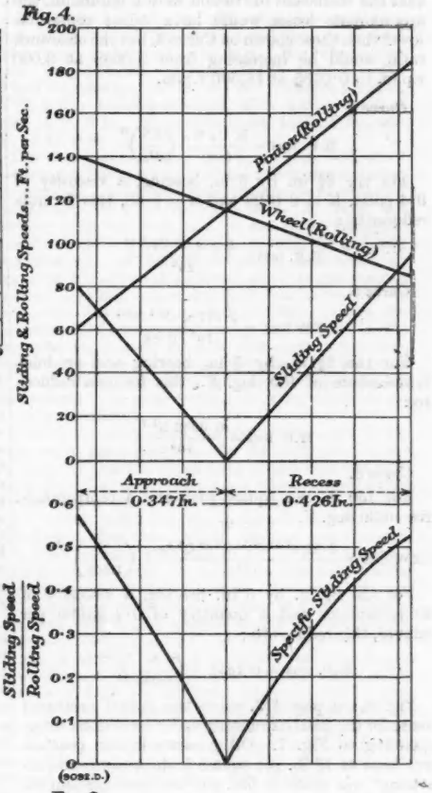



Fig. 5. SECTION AA

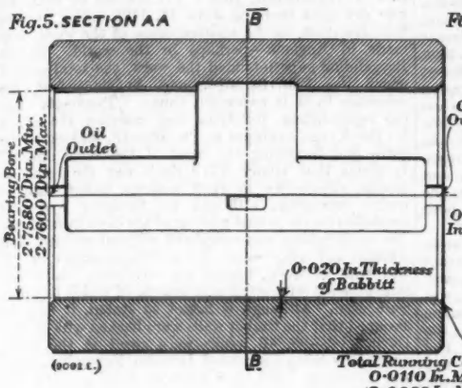
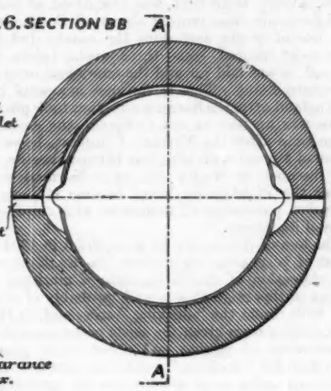



Fig. 6. SECTION BB




Total Running Clearance
0·0110 In. Max.
0·0080 In. Min.

Fig. 7.

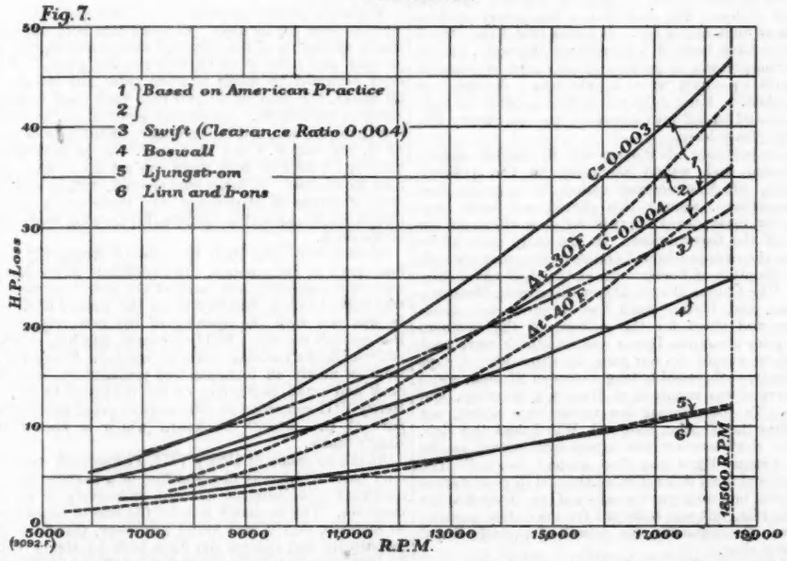
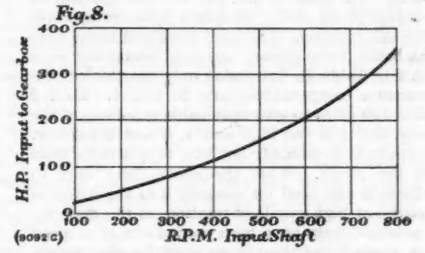



Fig. 8.




comparatively thick Babbitt there is a greater possibility of deformation from the true cylindrical form of the bearing when it is to operate at high speed and possibly at high temperatures.

Some 15 years ago, the British Thomson-Houston Company carried out tests on bearings suitable for speeds up to a maximum of 150 ft. per second and loads of approximately 150 lb. per square inch. The knowledge gained related to bearings operating at the moderate loads and speeds of turbine practice at that time. To obtain a lead regarding the type of oil ways and the proper amount of clearance necessary for high-speed operation, various papers and articles were studied and Fig. 7, herewith, shows the divergence of the information obtained. The losses, according to different authorities, for the $2\frac{3}{4}$ in. by 5 in. bearing illustrate the lack of design guidance for bearings running under the conditions of the set under consideration. Further, although there are similarities in the forms of the equations, there are also serious divergences. It would appear desirable to establish a series of mathematical formulæ applicable to each individual design of bearing, ratio of length to diameter, and the associated particular oil ways.

As a matter of interest, a comparison is given below of the formulæ used to arrive at the curves of Fig. 7, and, in Table II, on the opposite page, the total comparative calculated losses for the main gearbox and one auxiliary gearbox to effect a speed increase from 800 r.p.m. up to 18,500 r.p.m. are shown.

*Curve 1.*—For 120 deg. top and bottom turbine bearings,

$$\text{H.P. loss} = 1{\cdot}75\, d^2 l \frac{Z}{c}\left(\frac{N}{1{,}000}\right)^2 \times \left[1 + 1{\cdot}82\frac{pc^2}{ZN}\left(1 + 1{\cdot}27\,\frac{d}{l}\right)\right]$$

The first part represents the loss in an unloaded centrally-running bearing. The second part is a term proportional to the Sommerfeld variable, which includes a side-leakage factor.

For the $2\frac{3}{4}$ in. by 5 in. bearing, with a load of 190 lb. per square inch and an absolute viscosity of $58 \times 10^{-7}$ lb. per square inch per second, the above formula reduces to :—

$$\text{H.P. loss} = \frac{0{\cdot}384}{c \times 10^3}\left(\frac{N}{1{,}000}\right)^2\left(1 + \frac{10{\cdot}1 \times 10^7 \times C^2}{N}\right)$$

and is shown on Fig. 7 for clearance ratios of 0·003 and 0·004.

*Curve 2.*

$$\text{KW loss} = \frac{706 \times 10^{-6} \times d^{2{\cdot}72} \times l^{0{\cdot}945}}{(\Delta t \times \delta)^{0{\cdot}755}} \times Z^{0{\cdot}755} \times \left(\frac{N}{1{,}000}\right)^{2{\cdot}81}.$$

For the $2\frac{3}{4}$ in. by 5 in. bearing, a viscosity of 40 centipoises and a specific heat of 4·5 B.Th.U. per degree F. per gallon, this formula reduces to

$$\text{H.P. loss} = \frac{1{\cdot}13}{(\Delta t \times 4{\cdot}5)^{0{\cdot}755}} \times \left(\frac{N}{1{,}000}\right)^{2{\cdot}81}$$

and is shown on Fig. 7 for temperature rises of 30 deg. F. and 40 deg. F.

*Curve 3.*

$$\text{H.P. loss} = 0{\cdot}0681\sqrt{\frac{ZN}{P}} \cdot \frac{VW}{550}.$$

For the $2\frac{3}{4}$ in. by 5 in. bearing under consideration, this formula reduces to

$$\text{H.P. loss} = \frac{12{\cdot}55 \times N^{1{\cdot}5}}{10^6}.$$

It should be noted that, if the clearance ratio were arranged to give an eccentricity of such a value that the coefficient of friction were a minimum, the approximate losses would have values somewhat lower than those shown on Curve 4, but the clearance ratio would be increasing from 0·0088 at 8,000 r.p.m. to 0·0135 at 18,500 r.p.m.

*Curve* 4.

$$\text{H.P. loss} = \frac{K\,U_e\,W_e}{550}\left(\frac{ZN}{P_e}\right)^n.$$

For the 2¾ in. by 5 in. bearing, a viscosity of 0·4 poise, $K = 0{\cdot}0028$ and $n = 0{\cdot}58$, this formula reduces to:

$$\text{H.P. loss} = \frac{4{\cdot}475 \times (N)^{1.58}}{10^6}.$$

*Curve* 5.

$$\text{KW loss} = \frac{2{\cdot}577\ l\ d^{2{\cdot}7}\,N^{1{\cdot}7}}{10^5\,l^{0{\cdot}88}}.$$

For the 2¾ in. by 5 in. bearing and an inlet temperature of 100 deg. F., this formula reduces to:

$$\text{H.P. loss} = \frac{0{\cdot}0682\,N^{1{\cdot}7}}{10^5}.$$

*Curve* 6.

For 150 lb. per square inch and a temperature rise of 30 deg. F.

$$\text{KW loss} = \frac{2{\cdot}81\,d^{1{\cdot}45}\,l^{0{\cdot}55}\,Z^{0{\cdot}42}\,Q^{0{\cdot}4_2}}{10^3} \times \left(\frac{N}{1{,}000}\right)^{1{\cdot}42}.$$

For the 2¾ in. by 5 in. bearing, a viscosity of 40 centipoises and a quantity of 0·7 gallon per minute, this reduces to:

$$\text{H.P. loss} = 0{\cdot}1837 \times \left(\frac{N}{1{,}000}\right)^{1{\cdot}42}.$$

Fig. 8, on page 413, shows the actual measured losses for the gearbox running under conditions corresponding to Fig. 7. Oil pressure in the gearbox was kept at 15 lb. per square inch pressure and no attempt was made to find out the most economical quantity of oil or the minimum losses comparable with safe running. The total measured losses were 360 brake horse-power, agreeing reasonably with Col. 2 in Table II, but giving only one-third of the maximum comparative figure in Col. 1. Cols. 2 and 3 also seem to give reasonable estimates of the losses, but 1 is too high and 4, 5 and 6 too low. However, it is probably not wise to generalise from this one result. What the above facts seem to indicate is the need for research into the losses in bearings at high speeds of rotation, as the majority of practical tests have been carried out at a speed very much lower than is required for the present trend of mechanical engineering design.

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Water Power Development in France.—According to the Geneva correspondent of *The Times*, the 340-ft. dam at Genissat, in the Rhone Valley, will be completed within the next two months. As a result, a reservoir 120 ft. deep will be formed and will enable 2,300 million kWh per annum to be generated at Genissat itself and at Seyssel and Mondragon. A portion of this output will be reserved for Paris. The project also includes the reconstruction of the waterway and the provision of a number of irrigation pumping stations. An incidental consequence of the building of the dam will be the submergence of the Perte du Rhône, a geological curiosity, which causes the river to disappear underground and to reappear some distance lower down.

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Generation of Electricity.—The official returns rendered to the Electricity Commissioners show that 3,150 million kWh of electricity were generated by the authorised undertakings in Great Britain during September, 1947, compared with 3,105 million kWh during the corresponding month of 1946, an increase of 45 million kWh, or 1·4 per cent. During the first nine months of 1947 the total electricity generated was 30,439 million kWh, compared with 29,129 million kWh during the corresponding period of 1946, an increase of 1,240 million kWh, or 4·2 per cent. The total quantities sent out during September, 1947, and September, 1946, were 2,968 million kWh and 2,929 million kWh, respectively, an increase of 39 million kWh, or 1·3 per cent. During the first nine months of 1947 the total amount of electricity sent out was 28,711 million kWh, compared with 27,534 million kWh during the corresponding period of 1946, an increase of 1,177 million kWh, or 4·3 per cent.

## PORTSMOUTH DOCKYARD IN RELATION TO NAVAL POLICY.*

By Vice-Admiral L. V. Morgan, C.B., M.V.O.

Portsmouth Harbour has many advantages from the point of view of security. It is sheltered from the north, east and west; and until the advent of aircraft as weapons of offence, the harbour and dockyard were open to attack only by an enemy who had command of the sea. The entrance to the harbour is so narrow that it could be defended with great ease, the distance between the Round Tower and Fort Blockhouse being only about 250 yards. Portsmouth Harbour itself is a great sea-water lake some four miles long and two miles broad, and the position of the dockyard relative to the harbour renders it an eminently suitable port for naval purposes. In addition, at any rate in the old days, Portsmouth had a most valuable strategic position. Situated almost in the middle of the south coast of England, it was the most convenient centre for ships operating in the English Channel.

The invasion of 1066 found the south of England unprepared and without an adequate fleet. The *Saxon Chronicle* states that, in the opening months of 1066, a very large fleet was assembled at Sandwich, and for some time cruised about off Portsmouth and the Isle of Wight and along the coast; but when it was most wanted, some three weeks before William set sail, it was laid up and the crews had been allowed to return home. This is the one successful invasion of England after the Saxon occupation took place, when there was no fleet at sea to oppose the enemy. For some time after the Norman Conquest, however, the Channel was not a dividing line between hostile peoples, but became in reality an Anglo-Norman sea, and under the Plantagenet kings became still more the exclusive possession of monarchs who ruled on both sides of its waters.

The loss of Normandy by King John in 1204 was an event of very great importance; to England it meant the obligation of developing into a maritime power. It was in this reign that a wall, probably of mud, was first built round the "docking" area, and, at the same time, orders were given for sheds to be erected for the preservation of rigging and other ship's gear. The procedure for "docking" a ship was simple. She was drawn up as far as possible on to the mud of a creek or other suitable place at high water, the tide was allowed to leave her, and then a temporary wall or fence was built round her. It seems that King John's wall may have been of a permanent character, except for a semi-permanent portion which could be removed and built up again when a ship was "docked" or "undocked." King John's "dock" appears to have been allowed to fall into disuse by his son, Henry III, some 16 years later.

The importance of Portsmouth in British history has waxed and waned according to the political situation, which sometimes called for a major fleet and sometimes, though this should not have been often, for little naval support to give effect to the policy of the Government. In the early days of its history, the distance from London was a great obstacle to the adoption of Portsmouth as the chief naval shipyard. The Cinque Ports—Dover, Sandwich, Hastings, Romney, and Hythe—each had to produce a quota of men and ships for the defence of the southern shores; for example, Dover and Sandwich were each obliged to supply to the king 20 ships for 15 days every year, each vessel having a crew of 21 men, and a like service was required of Hastings, Romney, and Hythe. To the original five towns were added, not long after the Norman conquest, Winchelsea and Rye, and the confederation was afterwards known as the "Five Cinque Ports and Two Ancient Towns." The total normal force was not more than 56 ships and some 1,400 men, but, owing to the safety of the Channel under Norman rule, this was sufficient for the duties required of them. Consequently, the growth of a purely Royal Navy was slow.

Until 1299, in Edward I's reign, Portsmouth continued to be used for the assembly of ships on various occasions, but during the following 200 years the dockyard of Portsmouth appears to have been quite an insignificant establishment; there is scarcely any further mention of it in records until the time of Henry VII. Sea power was really first appreciated in the Fifteenth Century. The necessity for building up a King's fleet besides the Cinque Ports fleet, and with it the necessity for an efficient dockyard or base, was also fully appreciated. Henry V chose Southampton for his base, as it had fallen less into disuse than Portsmouth, but at his death the King's fleet was allowed to lapse, and it was left to Henry VII to build up a fleet once more in the face of a renewed threat from France. For his dockyard and naval base he chose Portsmouth.

During Henry V's reign, the Hamble river was used for laying up ships of war, but at his death the storehouse at Southampton, together with a number of ships, was sold to pay his debts, leaving a few hulks still laid up in the Hamble. Of these, the greatest was the Grace Dieu, of over 1,000 tons; she was burnt in 1439, and her remains, still lying in the river above Bursledon, have been discovered only recently. Therefore, when Henry VII wished to lay-up the Regent and the Sovereign, he was not bound to use the old berths, and chose the more convenient harbour of Portsmouth. The docking of a ship like the Sovereign in those days occupied 140 men for a day and a night at a cost of 2*l.* 13*s.* 2*d.* The cost of undocking was 12*l.* 8*s.* 2*d.*, which included the extra cost of breaking open the entrance. The proximity of Portsmouth to the Forest of Bere and the New Forest was an added incentive to make Portsmouth a naval repair base, and, from that time, Portsmouth became exclusively a naval port and Southampton remained as exclusively mercantile. Incidentally, it is possible that the beginnings of the yard at Deptford go back as far as 1485, so that it cannot be claimed definitely that Portsmouth is the senior dockyard.

After spending large sums of money on the fortification of Portsmouth, Henry VII started to build his new dry dock there on June 14, 1495. This was the first dry dock, in the modern sense of the word, ever made in England—perhaps in the world. Robert Brygandine superintended the work, the total cost of which was 193*l.* 0*s.* 6¾*d.*, and, in his patent, the reference to it is expressed thus: "Payments upon the reparalleling, fortifying and mending the dokke for the Kynge's shippes at Portsmouth, making of the gates and fortifying the head of the same dokke." It seems that Henry VII's dock was the result of foreign superiority in such matters rather than of native enterprise, although no foreigner was ever employed on the actual making of the dock in England. The undertaking was completed without accident and without any delay caused by unforeseen difficulty. It was built of wood, except the dockhead, which was strengthened with stone and gravel, of which 664 tons were used. Although it is not so stated, it may be assumed that the timber walls were backed with stones. During 1495-96, 46 weeks were spent in the work, operations being suspended between November, 1495, and February, 1496, and between April and July of the latter year.

When the Sovereign came out of this dock, 20 men were at work for 29 days "at every tide both day and night, weying up of the piles and shorys and digging of ye clay and other rubbish between the gates." The dock occupied 24 weeks and the gates and dockhead 22 weeks, the number of men paid each week varying between 28 and 60. Carpenters received 4*d.* to 6*d.* a day, sawyers 4*d.*, and labourers 3*d.* Four tons of iron at 3*l.* 14*s.* and 4*l.* a ton were used. In the immediate vicinity of the new dock there was set up at least one new storehouse. A forge was erected, with a regular staff of smiths in attendance, and there was a horse-driven engine, as well as buckets, for drawing water out of the dock.

None of the ships built by order of Henry VII was laid down at Portsmouth. His additions to the Navy were not numerous, and most of the new construction was carried out at Smallhythe on the Rother in Kent. It was not until the opening of the new reign that Portsmouth became a building centre, and has, on and off, remained a building centre to this day. Henry VII's work in nearly all branches was preparatory, but the dock and small beginnings of the dockyard to which Henry VIII succeeded in 1509 were situated about that part of the present Dockyard which is known as King's Stairs.

At the accession of Henry VIII, Portsmouth was the only place which was in possession of a harbour and a dockyard establishment devoted exclusively to naval purposes. The tendency was for the size of new ships to increase, and it was found necessary, therefore, to reconstruct and enlarge the dock built by Henry VII. In 1544, war was declared against Scotland and France once more, and the French carried out a successful attack on the Isle of Wight, making a landing at Brading on July 20, 1545, while their fleet lay at St. Helen's, threatening the English fleet at Portsmouth. This was undoubtedly the cause of Portsmouth being partly abandoned for the next hundred years, and led the newly appointed Navy Board in London to develop, first, the dockyard at Deptford, and subsequently Woolwich and Chatham.

Elizabeth was parsimonious in respect of the upkeep of her Royal ships, and particularly over the upkeep of the Dockyard at Portsmouth; but she was the first sovereign to maintain a small permanent naval force, of about 35 ships of all classes. During her reign, stone was used for the first time in the preparation of wharves. Although the Queen allowed Portsmouth to decline as a dockyard, it was used considerably during her reign as a harbour. During the reigns of the first two Stuart kings, the fortunes of Portsmouth and the Royal Dockyard did not improve, and the dockyard

* Paper read at a meeting of the Institution of Naval Architects, held in Portsmouth on September 23, 1947. Abridged.

and Navy generally were allowed to relapse into a state of decay. There was no set determination, continuing from reign to reign, to maintain a certain standard of naval strength, and consequently Portsmouth Dockyard suffered. Like the Navy itself, it was sometimes in a state of almost complete ruin. The placing of Portsmouth Dockyard on a reasonably permanent basis really dates from the Commonwealth, and, before the end of the Seventeenth Century, Portsmouth was recognised as the chief naval centre of England, as it is to-day.

The exhaustion of the country after 18 years' struggle with Spain caused a good deal of national decadence, but one man seems to have been in earnest in his endeavours to improve Portsmouth Dockyard, and that was George Villiers, later the first Duke of Buckingham. It was he who initiated such improvements as made possible its progress in the latter half of the century. The dry dock, which had been completed in 1496, had existed continuously up till now, and had even been enlarged, but in 1623 it was filled in with stones, that it might be better preserved against the violence of the sea. In 1627, special Commissioners, appointed through the exertions of Buckingham to inquire into the state of the Navy, discussed the condition of the dockyard at Portsmouth. An estimate was prepared for the cost of the building of a new dock, but the death of Buckingham came at a most inopportune time, and nothing more was done till 1630, when the famous Phineas Pett, a noted shipbuilder, declared that the ebb and flow of the tide in Portsmouth Harbour was insufficient, and it was recommended that the royal ships should in future lie up in Fareham Creek. This proposal was shelved, but in 1635 the need of a royal dock on the south coast was again felt, but on this occasion it was suggested that the new structure should be at the Hamble River "as one of the securest and most convenient places."

The next proposal was to set up a wholly new establishment on the Gosport side, to consist of a new dock, storehouses, workshops, and timber yard. In 1636, there was a return to the old scheme, and the officers of the Navy seem once more to have favoured Portsmouth, and suggested that even new storehouses and workshops at Portsmouth were of no great value to His Majesty's service without a dry dock. The proposed dock had now been under discussion for nearly ten years, and it was not until the Commonwealth was firmly established that the work was carried out, and completed in 1658. The Government provided the material and paid the contractors 2,100*l.* for the work, 500*l.* of which was provided by the Portsmouth Corporation, and under the Commonwealth administration the port made rapid progress as a naval base. From 1649, Commissioners were appointed to the Royal Dockyards, and Commissioners or Admirals Superintendent have been appointed ever since. At the latter part of Charles I's reign, Portsmouth Dockyard was on a fair road to prosperity, though still overshadowed by the Thames yards; but from the middle of the Seventeenth Century it was to advance without any of those major periods of depression which had marked its earlier history.

British sea supremacy was first threatened during the Dutch war of 1652 to 1654, the first of three purely naval wars. Throughout the Dutch wars, the huge Dutch fleet and seaborne trade endeavoured to sail up and down the narrow seas unmolested, and, as was natural, this again tended to give the Royal Dockyard of Portsmouth pre-eminence. At the end of the first Dutch war, the question of the supremacy of the seas was still in doubt, and at the end of the second Dutch war, 1664 to 1667, even more in doubt; and one reads: "Led by fresh deserters, De Ruyter raided the Thames and burnt and captured four British battleships"—the most shameful incident in the history of the British fleet, or, put more fairly, in naval administration. Samuel Pepys had become Clerk of the Acts, virtually Secretary of the Navy Board, in 1660, holding this appointment till 1673, after which he became Secretary of the Admiralty till 1679. Pepys was one of the greatest naval administrators, and some of his outstanding reforms still live to this day.

After the end of the second Dutch war, Pepys was not long in bringing his reforms into practice, and, although the Royal Navy and Royal Dockyards undoubtedly waned after that war, it was largely due to his energy and skilful administration that a successful third Dutch war was fought, 1672 to 1674. In 1667, 600,000*l.* was voted for the building of 30 new naval ships, and Portsmouth got its quota. The money for a new dry dock was voted in 1662, although there seems to be some doubt when the dock was completed. Additional storehouses, boat-house, and wharves were also built at this time, to be followed in 1664 by a mast-house and gun-wharf. This time of naval activity and expansion came to an end, temporarily, in 1679; then came five years of rapid decay. In fact, the whole period from 1679 to 1684 was a lamentable one, and Portsmouth Dockyard experienced the same neglect as characterised naval administration in other directions. However, during Pepys's second term as Secretary of the Admiralty, 1684 to 1689, rapid progress was once more made; one dry dock at Portsmouth was repaired in 1685, and a further single dry dock, 20 new storehouses, and additional wharves were built in the same year. The single dry dock referred to, may be that for which money was voted in 1662. In an endeavour to tighten up the administration, Pepys issued instructions to the Commissioners of the Dockyards, dated April 19, 1686, which required the Commissioner, or Admiral Superintendent as he is called to-day, "to reside in the dockyard in the dwelling house usually enjoyed by the Commissioner of the yard there." They conferred on him a salary of 500*l.* and a staff of two clerks, at salaries of 50*l.* and 60*l.*, respectively. The Admiral Superintendent has 26 clerks in his own office to-day and there are 1,209 in the Dockyard altogether. The patent also required all orders to the yard officers to pass through his hands.

The wall round the Dockyard was one of the early activities of the Eighteenth Century; it was begun in 1704 and finished in 1711, and still stands in its original form between the Main Gate and Marlborough Gate. Broadly speaking, this century was a period of continuous growth of the Royal Navy and Portsmouth Dockyard, though there were periods of relapse and lethargy between wars. During the wars of the Spanish Succession and the Austrian Succession, Great Britain came into conflict with Spain and France, but, after the peace of Aix-la-Chapelle in 1748, once more fell into the trap of hopeless lethargy; and once again the Navy and Portsmouth Dockyard were allowed to wane. The Seven Years' War brought nothing but honour to the Royal Navy, but after the peace, the Navy, and again Portsmouth Dockyard, were once more allowed to deteriorate. When Britain was engaged in the American War of Independence, from 1775-83, France, Spain, and Holland adopted a policy of revenge, France joining in in 1778, Spain in 1779, and the Dutch in 1780. The Navy was sorely in adversity, and the Treaty of Versailles which ended the American War of Independence was one of humiliation so far as Britain was concerned.

After the American War of Independence the people of Britain came to their senses. The Navy and Portsmouth Dockyard expanded and improved once more, and continued to do so up to the time of the French Revolution in 1789, and, indeed, right through the Napoleonic Wars till the end of 1815. In 1793, there were 113 ships of the line, and a grand total of 304. During the war with France, this number increased to 125 ships of the line and a grand total of over 700. In 1809, there was a grand total of 722 ships in the Royal Navy. In 1783, 65,198*l.* was spent on the enlargement and improvements of Portsmouth, Woolwich, Chatham, and Plymouth Dockyards; Portsmouth absorbing no less than 43,000*l.* The expenditure covered large reclamation of land, and the building of storehouses, workshops, and wharves. Despite this expansion, towards the end of the Eighteenth Century corruption in the Dockyard was allowed to creep in once more, and Lord St. Vincent wrote in 1799: "Nothing but a radical sweep in the dockyards could cure the enormous evils and corruptions in them." This situation was not thoroughly rectified until Queen Victoria's reign.

In December, 1797, the first steam engine was installed in the Dockyard for pumping docks. In the early part of the Nineteenth Century, a canal between London and Portsmouth was planned in 1817 and again in 1825. In fact, in 1817 a Bill was actually passed in Parliament to this end, though the canal itself was never started. In this way, it was hoped to build up an easy and cheap transport system between London and the premier naval port.

After the great war with France, and true to our early history, decay and reduction in all branches of the Service and Dockyards set in. However, the pendulum began to swing back again towards the middle of the Nineteenth Century, when not only was corruption in the Royal Dockyards greatly lessened, but considerable improvement was made in Portsmouth Dockyard itself. About the middle of the Nineteenth Century, rightly or wrongly, a large sum of money was spent on the shore defences of Portsmouth, on account of the French scare in 1843, when an invasion was seriously feared. At any rate, it was felt that the French contemplated an attack on Portsmouth.

The first wooden paddle-steamer built and launched in Portsmouth Dockyard was the Hermes. She was coppered at Portsmouth and then sent up the Thames to have her engines fitted; the *Hampshire Telegraph* of June 27, 1835, stated that this ship would "then be employed on the packet service." The first screw vessel to be built in Portsmouth Dockyard was the Rifleman, a steam gun-vessel; she was floated out of dock in August, 1846. She was masted the next day and took on board 200 tons of iron ballast. Like the Hermes, she proceeded up the Thames to have her screw-propeller engines fitted, which were manufactured by Messrs. Miller and Ravenhill. Her armament was six guns, two pivot shell guns and four broadside medium 32-pounders; at that time, comparatively heavier than in any other steamer in the Service.

The last sailing ship to be built in Portsmouth Dockyard was the Leander, in 1848. Her bow was very bluff, which enabled two guns on each deck to be fired right ahead in line with the keel. Her dimensions were: length on the water-line, 181 ft. 4½ in.; length of keel for tonnage, 148 ft. 11½ in.; extreme breadth, 50 ft. 9 in.; breadth moulded, 49 ft. 4 in.; depth of hold, 15 ft. 8 in.; draught forward, 13 ft. 5 in., and aft, 16 ft. 9 in.

The two plans, Figs. 1 and 2, on page 416, show Portsmouth Dockyard in 1754 and its expansion during the centuries. As stated above, the Dockyard remained insignificant until Henry VII's time. In 1485, the first dry dock was built, and the size of the Dockyard was then little over eight acres. In 1623, the dry dock was filled up. In 1650, there was no mast-house, no dry dock, 100 or less shipwrights, and only one team of horses. In 1656, a new dry dock was ordered to be built, and this was completed in 1658. During the Commonwealth, two acres were added in 1658 on the east side, about seven more in 1663 on the south side, and nine more in 1677 on the east side. On February 28, 1662, money was voted for a second dry dock, but there seems to be some doubt as to when this dock was actually completed.

During the Eighteenth Century, Portsmouth Dockyard made great progress. In the early part of the century, reclamation of ten acres of mud-land was commenced on the north side, upon which further storehouses and a wharf were built, and about 18 acres were added, extending the dockyard southwards to the present Main Gate, which, together with the wall, was built between 1704 and 1711. In 1723, George I added about 17 acres by further reclamation, making the area approximately 71 acres. Between 1753 and 1793, land was reclaimed from time to time, including the area behind the present South Railway Jetty, known as Watering Island. In 1802 a new basin, now known as the No. 1, or Ship Basin, was opened, and saw-mills and a steam pumping engine, metal mills, and block mills were erected. Around 1843, 17 acres of land were acquired to provide for the adoption of steam in the Navy. A new basin, the No. 2, or Steam Basin, was constructed, and four new docks and several large buildings were erected. The basin was opened by Queen Victoria on May 25, 1848.

In 1864, the work was commenced on what was known as the "Dockyard Extension," which included the absorption of about 84 acres of land, occupied partly by old fortifications, and an area known as Pest House Fields; the reclamation of about 93 acres of mud-land was also carried out. Parts of these areas, however, have since been allocated for purposes other than those of the Dockyard. By 1860, the size of the Dockyard had already reached 99 acres, which included 11 docks, one of which, that north of No. 5 Slip, has since been abandoned and filled in; and two basins, together covering 10 acres. The extension increased the size of the Dockyard to 261 acres, and included the addition of Nos. 3, 4, and 5 basins, three docks, two locks, and 13,000 more feet of wharfage, two further docks being subsequently built. Four of these docks were capable of receiving the largest ships of the Navy. The excavation of these later basins and docks was largely executed by convict labour and the material excavated was used for reclamation around Whale Island, which increased in size from 11½ to 74 acres, and upon which is now established the Gunnery School, H.M.S. Excellent.

Between 1888 and 1912, further small additions, totalling 15 acres, were made in the Dockyard, mostly to the eastward of Marlborough Gate; while just before the 1914-18 war basins Nos. 3, 4 and 5 were altered to form one large basin, the present basin No. 3, and at the same time the two large "C" and "D" locks were constructed to allow capital ships to enter the basin, these locks also being arranged for use as docks. Between 1938 and 1944, five acres of land were purchased outside Marlborough Gate to bring the area known as the Marlborough Salient into the Dockyard, this salient of privately-owned land having restricted dockyard development for some time. The present area of the Dockyard, including the Tidal Basin, is upwards of 290 acres, but negotiations are proceeding to take in 45 further acres of land, not including that required for barracks purposes. There were at one time five building slips used as such, but at present only one of these, which has been very considerably enlarged, is used for building, the rest having been appropriated for other purposes.

The original Steam Factory at Portsmouth was primarily concerned in making boilers. When it was put up, it was the Admiralty policy to make boilers for the fleet, but to engine the ships from private firms. That did not last long, and the Steam Factory, and indeed the main factory in Portsmouth Dockyard to-day, as in other Dockyards, deals only with repairs. Since the latter part of the Nineteenth Century and the early part of the Twentieth, the workshops have been gradually and systematically brought up to date by

# DEVELOPMENT OF PORTSMOUTH DOCKYARD.

*Fig. 1.* PORTSMOUTH DOCKYARD 1754.

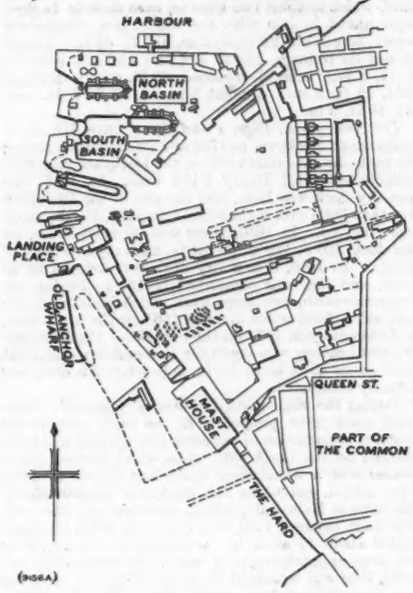
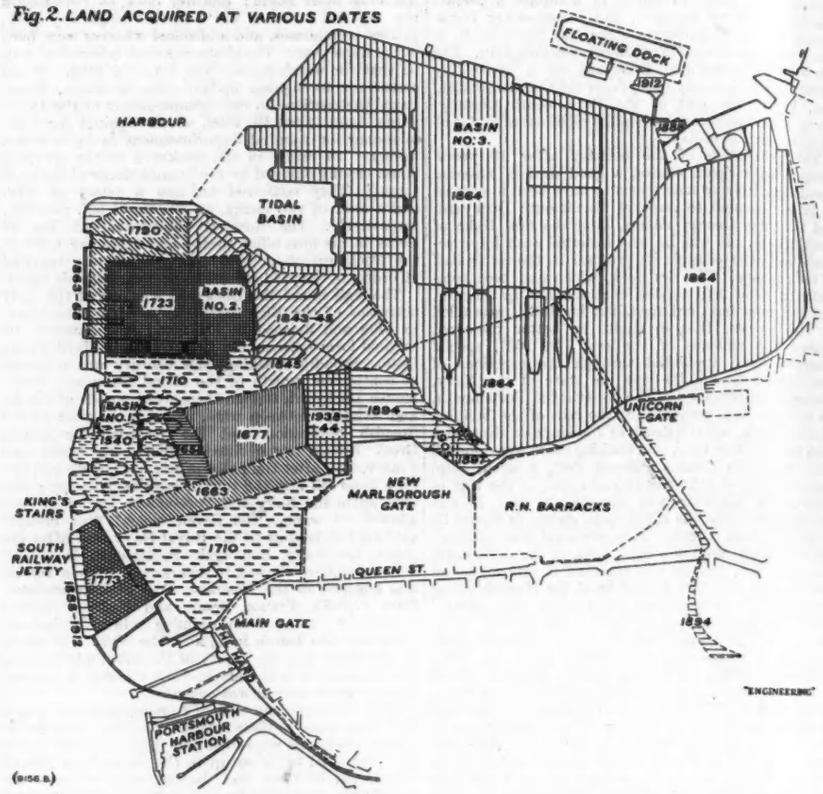



*Fig. 2.* LAND ACQUIRED AT VARIOUS DATES




the addition of modern engineering and electrical factories, boiler shop, smitheries, shipbuilding shops, ship-fitting shops and storehouses. To-day there are 14 docks and four locks in which ships can be docked down (a 15th dock being permanently occupied by H.M.S. Victory), one floating dock and various boat slips; and the large building slip has been equipped with modern cranes in place of derricks.

From the middle of the Nineteenth Century, Portsmouth Dockyard progressed steadily until 1919, because Britain was faced with the German threat towards the end of the Nineteenth Century and early Twentieth Century, culminating in the 1914-18 war. It suffered a decline and unemployment after that war, and not until about 1937 was it realised that we were faced with yet another crisis. Serious efforts were then made to build up the fleet and modernise Portsmouth Dockyard still more. There followed, of course, the Second World War.

The steady and regular building of large naval ships at this yard, which had been the policy for the last 20 years or so of the Nineteenth Century, was continued up to the latter part of the First Great War, the series of battleships beginning with the New Zealand in 1903 and ending with the Royal Sovereign in 1917. Although only two of these ships, the Queen Elizabeth and the Royal Sovereign, remain in existence as warships, they all contributed to naval history in one or both of the Great Wars, and particular mention should, perhaps, be made of three of them. The Dreadnought, built in record time between early October, 1905, and the end of 1906, inspired by the mind of that great sailor, Lord Fisher, and designed by Sir Phillip Watts, Director of Naval Construction, was to create some sensation among major naval Powers and set the lead and the pattern in many important aspects of design for all capital ship construction for many years. The Iron Duke, completed early in 1914, was flagship of the Grand Fleet in the early years of the first Great War, and played a worthy part in that application of sea power which in large measure was responsible for the defeat of Germany. The Queen Elizabeth has a striking record of war service in both Great Wars. Completed about the end of 1914, she was employed in 1915 in the bombardment of the Turkish positions in the Gallipoli peninsula, and later became the flagship of Earl Beatty in the Grand Fleet. She took an active part in the second Great War, largely in the Mediterranean.

The steady increase in size of capital ships in the first quarter of the present century has reached the stage where the building of modern capital ships is beyond the physical limitations of the slip at Portsmouth Dockyard, and it may be that the Royal Sovereign will have been the last battleship to be built at this yard. At any rate, the building of warships at Portsmouth has been restricted since 1917 to cruisers, destroyers and submarines.

This factor of the size of modern battleships, and the limitations imposed on naval expansion by the Washington and London Treaties, have tended towards the use of Portsmouth Dockyard largely for the reconstruction, refit and repair of warships, and in this capacity the yard has played a considerable part during the past 30 years. The lessons learned in the first World War regarding the need for protection against underwater attack by torpedoes resulted in the fitting of bulges to all existing capital ships, and between 1915 and 1929 this large structural alteration was carried out at Portsmouth, concurrently, in many cases, with other important work of modernisation, in about a dozen battleships and two aircraft carriers.

The work of reconstruction, refit, and repair of naval ships was Portsmouth Dockyard's main contribution to the development and maintenance of the Navy during the period between the two Great Wars, and in particular during the recent war, when the port was the principal naval launching base for the great attack on the Normandy coast in June, 1944. Apart from the preparation of hundreds of vessels for the attack, the building of many of the components of the Mulberry Harbour was carried out in the dockyard, and the headquarters of the Allied Naval Commander-in-Chief was established in close proximity.

In keeping with its position as premier naval port, Portsmouth has been closely associated with research, experiment, and training affecting the technical equipment and personnel of the Navy. The establishments concerned with training and development in naval gunnery, H.M.S. Excellent, torpedoes and under-water weapons, H.M.S. Vernon, communications, H.M. Signal School, and navigation, H.M.S. Dryad, were all established in Portsmouth or its close vicinity, as was also the radar and electrical training establishment, H.M.S. Collingwood, in recent years. In the field of technical and scientific development a great deal of early work in the technique and practice of electric welding and underwater welding and cutting was carried out at Portsmouth Dockyard. It is interesting to note in these days, when scientific research is given a good deal of publicity, that the Admiralty Chemical Laboratory was established in Portsmouth Dockyard in 1870, and the Central Metallurgical Laboratory in 1936, from which dates these establishments have been gradually built up. The Admiralty Experiment Works was established at Haslar under the superintendence of R. E. Froude in 1887, when it was transferred from Torquay. Perhaps less well known is its younger neighbour at Haslar, the Admiralty Oil Fuel Research and Experiment Establishment, where research into problems concerning fuels and boiler development are carried out. Since 1900, Portsmouth Dockyard has built eleven battleships, ten cruisers, four destroyers and seven submarines.

I hope that, short though this paper is, it may stimulate a few to read more of the romance and history of this famous Dockyard at Portsmouth. I think it has been shown that the British Fleet, and therefore the Royal Dockyard of Portsmouth, waxes and wanes according to our foreign policy of the time, which policy may have appeared to require from time to time a greater or lesser sea power in the background to give effect to the policy. When the British Navy and its means of maintenance have been allowed to wane, and even for a time to be shelved and forgotten, prolonged peace has not necessarily ensued. Our weakness at sea has, in fact, more than once been a contributory factor to another war. I would like to finish by quoting, from one of Professor Callender's books, words which we should, I think, be wise to remember: "A Navy (and indeed a Royal Dockyard) cannot be improvised any more than a garden. Both need unstinted time and care and both can be ruined by a few years of neglect."

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Return to Service of S.S. "Esperance Bay."—The work of refitting the steamer Esperance Bay has been completed. The work of reconversion from a troopship was carried out by Messrs. Swan, Hunter, and Wigham Richardson, Limited, at their Wallsend-on-Tyne yard, and during reconversion the opportunity was taken of making many improvements to the public rooms and passenger accommodation.

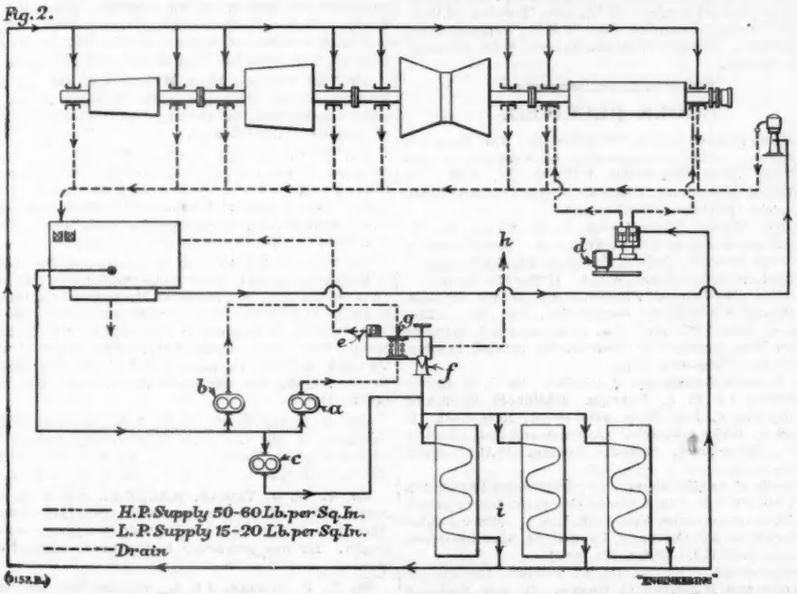
Bridge Repairs in Australia.—A novel method of relieving the load on a bridge truss, using Bailey bridging material, to enable repairs to be carried out, has been reported from the Department of Main Roads, New South Wales, Australia. A triple-truss Bailey girder was constructed above the bridge decking, parallel and adjacent to the truss to be repaired. A timber beam was then placed under the bridge transoms, directly below the Bailey girder, and was slung from the girder, through the decking, by a series of pairs of long bolts, the upper ends of which passed through holes in short transoms resting across the bottom chords of the triple-truss girder, and the lower ends of which passed, on either side of the timber beam, through holes in steel plates which carried the beam. The long bolts were then tightened, and as the load of the bridge was taken by the Bailey girder, the main truss of the bridge was left free for repairs.

# 32-MW TURBO-ALTERNATOR AT WILLESDEN.

THE ENGLISH ELECTRIC COMPANY, LIMITED, LONDON.

FIG. 1. HOUSE ALTERNATOR, EXCITERS AND DIRECT-CURRENT GENERATORS.

*Fig. 2.*




## 32-MW TURBO-ALTERNATOR SET AT WILLESDEN.

THE Northmet Power Company, which was incorporated in 1900 as the North Metropolitan Electric Power Supply Company, serves an area of 670 square miles in Middlesex, Hertfordshire and Essex from power stations at Brimsdown and Willesden. An interesting development at the Willesden power station has been the replacement of nearly all the low-pressure plant by two 32-MW sets, which are supplied with steam at a pressure of 1,400 lb. per square inch. and a temperature of 960 deg. F.

The first of these high-pressure sets to be installed has been constructed by the English Electric Company, Limited, Queen's House, Kingsway, London, W.C.2, and is illustrated in Fig. 3, on page 420, which shows the plant from the steam end. The set, which has an output of 32 MW and runs at a speed of 3,000 r.p.m., is of the three-cylinder impulse-reaction type, the high-pressure and intermediate-pressure portions being of the single-flow impulse design, while the double-flow reaction principle is employed in the low-pressure cylinder. There are fifteen stages in the high-pressure cylinder, seventeen in the intermediate, and ten on each side in the low-pressure stage. The nozzles throughout are of the English Electric Company's design. The diaphragms are built up in halves, and are fixed so that all the expansion takes place away from the centre line. The diaphragm openings are therefore always maintained co-axial with the shaft at all temperatures. In the high- and intermediate-pressure cylinders, the impulse blading, which is of stainless steel, is accurately machined all over. It has T-section roots which fit into corresponding grooves machined in the peripheries of the rotors, in accordance with the company's standard practice. On the low-pressure turbine, the blading is of the reaction type, and is of stainless iron, the last two rows being provided with tungsten-steel shields to prevent erosion.

Thrust bearings of the Michell type are provided on all three turbine rotors, those for the high-pressure and intermediate-pressure rotors being of the adjustable type, so that the axial clearances between the stationary and moving parts of the turbine can be regulated to compensate for differential expansion as the running conditions change from cold to hot. The low-pressure thrust bearing is only used for locating the rotor, as with the double-flow construction there is no out-of-balance thrust. The high-pressure cylinder casing is machined from a 0·5 per cent. molybdenum steel forging, while such other portions of the turbine as are subjected to temperatures exceeding 450 deg. F. are made of cast steel. The remainder of the steam side is constructed of close-grained cast iron.

The governor is of the centrifugal, totally-enclosed type, and controls the governing valves through an oil-operated relay system. The valves are contained in two steam chests, one on each side of the turbine. There are two main throttle valves, one in each chest, with one full-load valve in one chest and an overload valve in the other. Each chest also contains an emergency trip valve. This is spring-operated, but is under the control of the oil relay system. The steam chests are machined from 0·5 per cent. molybdenum steel forgings and are supported from the foundations by flexible steel plates. In the event of failure of the oil relay system associated with the governor, all the valves close automatically. An overspeed device, which will shut down the turbine if its speed exceeds the normal figure by 12 per cent., is also fitted.

The layout of the lubricating-oil system is shown diagrammatically in Fig. 2. The main oil pump *a* for the forced-lubrication system of the turbine, main alternator and gearing, is mounted in the pedestal between the high-pressure and low-pressure cylinders, instead of in the more orthodox position in the steam-end pedestal. This has been done in order to keep the pump away from the high temperature prevailing in the latter position. The pump is of the double-helical gearwheel type and is driven by spur gearing from the intermediate-pressure shaft. It has a capacity of 350 gallons per minute at a discharge pressure of 50 lb. to 60 lb. per square inch. A motor-driven pump *b* of the same capacity is used for starting up or shutting down. This takes the place of the more usual turbine-driven auxiliary oil pump, which has been omitted, owing to the extra high pressure of the initial steam supply. This pump comes into operation automatically when the oil pressure in the relay system falls below about 40 lb. per square inch.

Motor-operated barring gear is mounted between the turbine exhaust and the main alternator, so that the shafts can be rotated slowly during the warming up or cooling down of the turbine. A motor-driven oil flushing pump *c* of 150 gallons per minute capacity, discharging at 15 lb. to 20 lb. per square inch, supplies oil to the bearings when the barring gear is in operation. In addition, a motor-driven plunger-type oil jacking pump *d* supplies oil at 1,000 lb. per square inch to the alternator bearings when starting up the barring gear. In Fig. 2, the relief, reducing and non-return valves are shown at *e*, *f* and *g*, respectively, and the high-pressure supply to the governor relays at *h*. The oil coolers are indicated at *i*.

The turbine exhausts into a condenser of the English Electric Company's twin-shell type. This condenser, which is illustrated in Fig. 4, on page 420, is capable of maintaining a vacuum of 28·5 in. of mercury, with the barometer at 30 in., when the plant is developing its maximum continuous rating, and when it is supplied with 23,000 gallons of cooling water per minute at a temperature of 70 deg. F. The condenser tubes are of solid-drawn brass, of standard commercial 70/30 alloy, with an outside diameter of $\frac{3}{4}$ in. and a thickness of No. 18 s.w.g. They are expanded into the rolled-brass tube plates at the inlet end, and are secured by screwed ferrules with fibre and linen cord packing at the outlet end. They are thus free to expand. The water box of the condenser has been tested hydraulically to a pressure of 60 lb. per square inch gauge, while the steam side has also been tested hydraulically to a pressure of 15 lb. per square inch gauge.

The rotary air pump is of the Leblanc type and is capable of extracting 102 lb. of dry air per hour, equivalent to about 200 lb. of saturated air per hour, at 28$\frac{1}{2}$ in. vacuum. It is driven by a 94-h.p. induction motor. The steam air ejectors, which are used as a standby to the rotary air pump, are situated on the turbine operating platform. To assist starting-up, a single-stage exhauster, which is operated at reduced pressure from the high-pressure steam mains, is also supplied. This exhauster is connected in parallel with the steam-operated air ejector and the rotary air pump. It is capable of exhausting a closed space of 1,000 cu. ft. to a vacuum of 20 in. of mercury in one minute. Two extraction pumps, which were manufactured by Messrs. Drysdale and Company, Limited, Glasgow, and are of that firm's vertical two-stage "Pervac" type, are provided. Each of these is capable of dealing with the whole of the condensate of the turbine, together with the make-up water from the evaporating plant. They are driven by 35-h.p. induction motors of the English Electric Company's make.

Feed heating is effected by three high-pressure heaters, which draw their operating steam from separate stages on the intermediate pressure turbine. There is also a de-aerator, which takes its steam supply from the exhaust of the same cylinder. The low-pressure heater is supplied from one of the stages of the low-pressure turbine. All the heaters are of the English Electric Company's construction. The evaporator, which was constructed by Messrs. Aiton and Company, Limited, Derby, is of the double-effect dual-purpose type, and can be operated either by high-pressure steam or by steam bled from one of the stages on the intermediate pressure turbine. The feed-heating equipment is capable of heating the condensate to a temperature of 360 deg. F. when the plant is developing its maximum continuous rating. In order to safeguard the turbine in the event of a failure of a feed-heater tu be

emergency float-controlled drains are installed in suitable positions on each high-pressure feed heater, while non-return valves are fitted in all the bled steam pipes. In addition, alarm devices are provided in the steam space of each high-pressure heater.

The alternator, which has a maximum continuous rating of 30,000 kW was also made by the English Electric Company. It is wound to generate three-phase current at 33 kV and 50 cycles per second, its full load rating being 618 amperes at a power factor of 0·85. The regulation, when the maximum load is suddenly thrown off, gives a rise in terminal voltage of 30 per cent. at unity power factor and of 38 per cent. at 0·85 lagging power factor. The rotor is of the cylindrical type, the shaft and body being forged in one piece from annealed carbon steel. The bearings are of the spherically seated self-aligning and adjustable type, and are lubricated from the main turbine oil system as already described. Special precautions have been taken to prevent oil and oil vapour from the bearings from getting into the windings. Circulation of currents in the shaft is prevented by insulation placed under the outboard bearing pedestal. Six thermocouples are fitted between coils and wedges in the stator winding slots, the leads from which are brought out to a terminal plate fixed on the stator frame. The alternator and the cables to the switches are protected on the Merz-Price system, and in addition to the ring type current transformers required for this purpose, metering current transformers are also provided.

The main alternator and the house alternator have separate air coolers which receive their cooling water from the condenser circulating-water system. The finned tubes in these coolers are secured in brass tube plates at each end by screwed brass ferrules and packings. The water boxes are of cast iron. The general construction of the coolers is similar to that of the condensers, the water flowing through the tubes and cooling the air which passes over the tube fins. The main alternator can also be cooled by two external fans which have a capacity of 31,250 cu. ft. of air per minute, and are driven by 100-h.p. motors running at 973 r.p.m. Alarms are provided to give warning if the temperatures of the cooling air become abnormal.

Reduction gearing is fitted at the end of the main shaft of the set through which the auxiliaries are driven at a speed of 1,010 r.p.m. This gearing consists of two sets of double-helical single-stage reduction gears, one of which drives a house alternator and three exciters, and the other two direct-current generators. This gearing is visible in Fig. 1, on page 417, which also shows the house alternator, exciters and direct-current generators.

The house alternator has an output of 800 kW when running at 1,010 r.p.m. It supplies three-phase current at 415 volts and a frequency of 50·5 cycles per second with a power factor of 0·8. The regulation conditions provide for a rise in terminal voltage of 9 per cent. at unity power factor when the full load is suddenly thrown off, and of 20 per cent. at 0·8 power factor. The general construction of the stator and rotor of this machine follows the Company's standard practice. It is also protected on the Merz-Price system. Coupled to the end of the house alternator are the main, pilot and house exciters. The main exciter has an output of 350 to 390 amperes at 322 to 253 volts, when running at 1,010 r.p.m. It has a quick response rate, with a voltage rise of approximately 375 volts per second in the initial stage. It is separately excited from the pilot exciter, a differential field winding enabling this excitation to be reduced to zero if required. The house-alternator exciter has a normal output of 275 amperes at 66 volts, and the pilot exciter delivers 15 amperes at 220 volts. These two machines are mounted back to back. A standby excitation unit, comprising an exciter, a pilot exciter, and a driving motor, is mounted on a combined bedplate separate from the machine.

The direct-current generators were made by Messrs. Metropolitan-Vickers' Electrical Company, Limited, and are used for supplying the boiler auxiliaries. Each generator is of the drip-proof type, and has an output of 700 kW at 500 volts at normal speed. The shunt fields are supplied at a pressure of 110 volts from a separate generator and the machine is cooled by an external fan capable of handling 10,000 cub. ft. of air per minute. Operation is on the Ward-Leonard principle.

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Building and Road Research for Scotland.—A branch Building Research station of the Department of Scientific and Industrial Research is to be established in Scotland. At the outset, the work will be largely advisory, but laboratories are to be equipped for dealing with the native building and constructional methods. A new substation of the Road Research Laboratory is also to be set up to investigate Scottish road problems, which differ from those farther south owing to such factors as climatic conditions and traffic density.

## INSTITUTION ELECTIONS.

Institution of Civil Engineers.

*Associate Member to Member.*—Mazhuvanchery Chakko Abraham, B.Sc. (Manch.), Colombo, Ceylon; Henry George Burns, M.B.E., Etawam, U.P., India; William Marshall Clark, O.B.E., B.Sc. (Cape Town), Johannesburg, S. Africa; Colin Cameron Kirby, St. Peters, Broadstairs, Kent; James Robertson, B.Sc. (Glas.), Dumfries; Albert Francis Rushbrook, M.B.E., B.Sc. (Eng.) (Lond.), Liverpool; George Alfred Reece Sheppard, M.A. (Oxon.), London, S.W.1; John Letham White, B.Sc. (Edin.), Edinburgh.

*Associate Member.*—Walter Peter Wingate Davidson, M.B.E., B.Sc. (Edin.), Edinburgh; Austin Gabriel Jennings, B.E. (Nat'l), Sligo, Eire; James McClusky, Glasgow; Edgar Snow Potton, B.Sc. (Eng.) (Lond.), Cardiff.

*Student to Associate Member.*—Henry Wise Baker, Jun., Glasgow, W.2; Earl Walshaw Bateman, B.Sc. (Eng.) (Lond.), Skipton; Eric Armitage Brook, M.Eng. (L'pool), Holywell, Flints.; Dudley James Clapham, B.Sc. (Eng.) (Lond.), Purley, Surrey; Reginald Crowther, Andover, Hants.; Michael Rex Horne, B.A. (Cantab.), Cambridge; James McKenzie Hoy, Currie, Midlothian; Patrick Stanislaus Kenny, B.E. (Nat'l), Richmond, Surrey; John Alfred Price, B.A. (Cantab.), London, N.W.3; Gordon Urwin, Cirencester.

Institution of Mechanical Engineers.

*Member.*—Joseph Nixon Bewsher, Warrington; Christopher Hodgson Booth, Sheffield; James Douglas, B.Sc. (Glas.), London, S.W.1; Humphrey Bain Hichens, M.B.E., B.A. (Cantab.), Johannesburg, S. Africa; Herbert George McClean, B.Sc. (Eng.) (Lond.), Chelmsford, Essex; James Wright MacFarlane, Glasgow, S.4; Rear-Admiral (E) Alexander Livingstone Penrose Mark-Wardlaw, R.N., ret., London, S.W.1; Lyell Thomas Campbell Pitt, O.B.E., Johannesburg, Transvaal; Donald Phillpott Sayers, B.Sc. (B'ham), Birmingham.

## BOOKS RECEIVED.

*It Might Happen Again.* Volume II. *The Navy and Defence.* The Autobiography of Admiral of the Fleet Lord Chatfield, P.C., G.C.B., O.M., etc. William Heinemann, Limited, 99, Great Russell-street. London, W.C.1. [Price 18*s.* net.]

*Newnes Plastics Manual.* By F. J. Camm, H. W. Gilbert-Rolfe and D. C. Nicholas. Second edition. George Newnes, Limited, Tower House, Southampton-street, Strand, London, W.C.2. [Price 17*s.* 6*d.* net.]

*Injection Molding of Plastics.* By Irlyn Thomas. Rheinhold Publishing Corporation, 330, West 42nd-street, New York 18, U.S.A. [Price 10 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 60*s.* net.]

*Low-Pressure Laminating of Plastics.* By J. S. Hicks, assisted by R. J. Francis. Rheinhold Publishing Corporation, 330, West 42nd-street, New York 18, U.S.A. [Price 4·50 dols.] Chapman and Hall, Limited, 37, Essex-street, Strand, London, W.C.2. [Price 27*s.* net.]

*Elements of Applied Energy.* By Professor Frederick T. Morse. D. van Nostrand Company, Incorporated, 250, Fourth-avenue, New York, U.S.A. [Price 6 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 30*s.* net.]

*Visible Speech.* By Ralph K. Potter, George A. Kopp and Harriett C. Green. D. van Nostrand Company, Incorporated, 250, Fourth-avenue, New York, U.S.A. [Price 5 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 25*s.* net.]

*Engineering College Research Council of The American Society for Engineering Education. Proceedings of the Annual Meeting, Minneapolis, Minnesota, June* 17 to 21, 1947. The Secretary, Engineering College Research Council, College of Engineering, State University of Iowa, Iowa City, Iowa, U.S.A. [Price 1 dol.]

*The Manchester Association of Engineers. Transactions.* Session 1946-47. Edited by T. Makemson, Secretary. The Secretary, The Manchester Association of Engineers, St. John Street Chambers, Deansgate, Manchester.

*60 Years with Men and Machines. An Autobiography.* By Fred H. Colvin, in collaboration with D. J. Duffin. Whittlesey House, McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 3·50 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 17*s.* 6*d.*]

*Manual of Mathematics and Mechanics.* By Professors Guy Roger Clements and Levi Thomas Wilson. Second edition. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 3·25 dols.] McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 16*s.* 6*d.*]

## PERSONAL.

Sir Gilmour Jenkins, K.B.E., C.B., M.C., Deputy secretary of the Ministry of Transport from 1941 until July, 1946, and subsequently joint Permanent Under Secretary of State at the Foreign Office in charge of the German Section, has been made Permanent Secretary of the Ministry of Transport in succession to Sir Cyril Hurcomb, G.C.B., K.B.E., who has been appointed chairman of the British Transport Commission.

Sir Reginald Hill, K.B.E., C.B., Deputy Secretary of the Ministry of Transport in charge of inland transport has been made chairman of the Docks and Inland Waterways Executive of the British Transport Commission. The full-time members of the Executive are Mr. Robert Davidson, M.Inst.T., Mr. John Donovan and Sir Robert Letch, M.Inst.T., and the part-time members, Mr. George Cadbury, M. Inst.T., Sir Hector McNeill, and Sir Ernest Murrant, K.C.M.G., M.B.E.

Mr. W. S. Farren, C.B., M.B.E., M.I.Mech.E., F.R.Ae.S., F.R.S., has been appointed to the board of Messrs. A. V. Roe and Company, Limited, Greengate, Middleton, Manchester. He will be responsible for directing the technical activities of the company.

Mr. W. A. C. Snook, O.B.E., has retired from the position of Rolling-Stock Engineer for omnibuses and coaches, London Passenger Transport Board, 55, Broadway, London, S.W.1.

Mr. T. T. Shephard, formerly attached to the office of the Chief Mechanical Engineer (Road Services), London Passenger Transport Board, for special duties, has been appointed to the new position of Rolling Stock Engineer (Road Services). His office is at the Board's Chiswick Works.

Mr. H. E. Sheardown, chairman of Messrs. Charles D. Holmes and Company, Limited, Hull, has been elected chairman for 1947-48 of the National Association of Marine Engine Builders. Mr. H. Ferrier, O.B.E., managing director of Messrs. Rankin and Blackmore, Limited, Greenock, has been elected vice-chairman.

Air Vice-Marshal G. A. H. Pidcock, who has been President of the Ordnance Board, Ministry of Supply, since August, 1945, has been appointed Director-General of Armament, Air Ministry.

Mr. F. C. Clarke, B.Sc., A.R.C.Sc., A.M.I.E.E., Principal of the College of Technology, Rotherham, is retiring next Easter and will be succeeded by Mr. C. L. Old, B.Sc. (Eng.), (Lond.), M.Sc.Tech. (Manch.), A.M.I.Mech.E., at present vice-principal, Royal Aircraft Technical College, Farnborough, Hampshire.

Mr. T. E. H. Birley, O.B.E., overseas representative of British Insulated Callendar's Cables, Limited, has been awarded the American Legion of Merit (Degree of Officer) in recognition of his work as assistant secretary on the War Cabinet Secretariat in Washington, U.S.A., from March, 1942, until August, 1945, where he served with the rank of Group Captain, Royal Air Force Volunteer Reserve, under the late Field Marshal Sir John Dill, G.C.B., D.S.O.

Mrs. F. D. Heywood, Ph.D., B.Sc., has been elected President of the Women's Engineering Society, 35, Grosvenor-place, London, S.W.1, for the year 1947-48. She succeeds Miss Winifred Hackett, Ph.D., B.Sc.

Mr. T. W. J. Temple, A.M.I.E.E., A.R.Ae.S., has joined the staff of the Newcastle-upon-Tyne district office of the British Thomson-Houston Company, Limited, Rugby. He was previously in the Leeds office of the firm.

Mr. V. T. Norman, A.C.A., who has held the office of chief accountant of the Coventry Gauge and Tool Company, Limited, Coventry, since 1936, has been elected to the board of directors as director and commercial manager.

After 18 years' service with the Consolidated Pneumatic Tool Company, Limited, 232, Dawes-road, London, S.W.6, Mr. A. E. Cutter has relinquished his position as publicity manager, which he has occupied since August, 1940, to take up the appointment of advertising manager with Messrs. Blaw-Knox Limited, Clifton House, Euston-road, London, N.W.1. Mr. Harold S. Parsons has been appointed publicity manager of the Consolidated Pneumatic Tool Company.

Messrs. J. H. Fenner and Company, Limited, announce that their export-sales division will be transferred to Marfleet, Hull, on November 7, and that their accounts department moves back from Cleckheaton to Hull on December 8.

As from December 1, the Mastabar Belt Fastener Company, Limited, 14, Westgate-street, Cardiff, are taking over the sales of the "Comet" conveyor-belt lacing system, for collieries in South Wales, previously dealt with by Messrs. Tom Smith and Clarke, Limited, Swansea. Similarly, sales in Lancashire, Cheshire, Staffordshire and North Wales, formerly handled by Messrs. J. H. Whittam, Limited, Burnley, will be taken over by the Mastabar Company, Avenue-parade, Accrington, Lancashire.

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scottish Steel.*—The new steel prices have not exercised any apparent effect on the demand, which is as insistent as ever, both on home and export account. It is understood that the Ministry of Supply are busy on a new authorisation scheme to bring allocations into line with the emergency conditions precipitated by the new export drive under the control of the Minister for Economic Affairs. In some quarters it is felt that the issue of authorisations covering purchases as far ahead as the first quarter of 1949 is a mistake, having regard to the complications and business disturbance that will result if and when the new authorisation scheme comes into operation and large numbers of these older authorisations have to be cancelled. The West of Scotland output has not yet suffered from the dislocation of coal deliveries arising from the present strikes in Scotland, but stocks have been reduced. The outputs of ingots and castings last week were nearly at the full-capacity level, and consumers generally received a good tonnage against their running contracts and orders. Re-rollers complained again of a marked shortage of billets and sheet bars, which tended to limit the output of sheets and other rolled products. Tube and boiler makers reported continued full-scale activity, with export and home business well blended. Pig-iron production is steady; the coke for the new blast-furnace at Clyde works is not yet to hand, and there is considerable speculation and doubt as to what will happen there. Steel scrap is in very short supply, and existing stocks have become lower.

*Scottish Coal.*—The West of Scotland coalfields have been gravely affected by the strike which paralysed output last week to the extent of about 140,000 tons of coal. The comparatively well-stocked position of users obviated any stoppage of industrial activity or of the public services, but the breakdown of production has weakened the winter stocking programme appreciably. In other respects, the market was rather featureless. Wagon supplies were fortuitously relieved by the stoppages at about 90 pits, but there is some concern regarding what will happen when normal coal production is resumed, as the wagon position is very difficult, and is expected to get worse during the shorter days. Fortunately, weather conditions have favoured the market, and space heating is still a negligible burden.

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*General Situation.*—Conditions in the Teesside iron and allied trades are keeping new business within narrow limits. Producers are greatly in arrears with deliveries and their embarrassing commitments preclude further extensive bookings. Customers are demanding larger deliveries but even priority buyers have to wait a considerable time for their quotas. Ironstone raised from the Cleveland mines is still on a disappointing scale, but pig-iron production is steadily expanding. While, however, the number of blast-furnaces operating in the Teesside area has risen to 27, their output is much below current needs and the shortage of pig still necessitates the use of heavy cast-iron and good steel scrap on an exceptionally large scale. Of the furnaces in blast, 19 are turning out basic iron, six hematite, and two ferro-manganese. Steel producers are extensively oversold.

*Foundry and Basic Iron.*—The scarcity of ordinary foundry pig-iron is seriously hampering operations at the plants turning out castings. Since the make of No. 3 Cleveland was discontinued, North-East Coast foundry pig consumers have had to rely almost entirely on deliveries of Midland brands, supplies of which are often irregular and inadequate. Substantial parcels of basic iron are passing promptly into use in the makers' own consuming departments and larger deliveries would be very welcome.

*Hematite, Low-Phosphorus and Refined Iron.*—East-Coast hematite manufacturers continue to supply satisfactorily the users' increasing requirements, but a little further increase in the demand may be difficult to meet. Low- and medium-phosphorus grades of iron are in considerably greater demand than sellers can supply, and the output of refined iron is steadily taken up.

*Manufactured Iron and Steel.*—Producers of semi-finished and finished iron have contracts to carry out which will keep them actively engaged until the next allocation period and steel manufacturers are encumbered by embarrassingly large commitments. Makers of steel semies are not yet able to cope fully with the users' pressing requirements and inferior products, as well as any available parcels of foreign material, are readily accepted. The commodities in greatest demand are prime sheet bars, blooms and billets, supplies of which are slightly less scarce than has been the case for some time. In the finished branches of industry the most urgent need is for a larger output of sheets, but the demand for railway requisites, shipbuilding material and colliery equipment is still intense.

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*Iron and Steel.*—More regular supplies of coke are reaching the blast-furnaces, but pig-iron supplies are short, and there is a marked scarcity of iron and steel scrap for re-melting. The operation of the staggered working hours scheme is getting into its stride at numerous works, but it has not been possible yet to apply it to all the works which are to come into the scheme; a considerable saving of power has been effected. More gas for the melting and heat-treatment furnaces is available, but it has not been possible to overtake the considerable arrears of deliveries of steel, the shortage of which is imposing short-time working in many departments. Makers of railway materials are endeavouring to cope with heavy orders for wheels, tyres, axles, buffers and springs for the building and repair of locomotives, carriages and wagons. Additional melting furnaces are being installed at railway-material works which are affected by the scarcity of steel, particularly axle steel. Wagon-repair shops have a great deal of work on hand and there is pressure for the completion of repairs of wagons which are needed in much greater numbers for the movement of coal from collieries to Sheffield works. A road-haulage transport system has been inaugurated to move coal from Derbyshire and Nottinghamshire deep mines to Sheffield works, in substitution for railway haulage, which is adversely affected by the wagon shortage. Some progress is being made with the conversion of armament shops to heavy machine-tool building. The demand for heavy and light machine tools is considerable, and delays in delivery are general. Engineers' small tools and edge tools are in great demand.

*South Yorkshire Coal Trade.*—Production is improving a little and several pits continue to exceed their target outputs. The demand is greater than the supply and it has not been possible to build up reserve stocks which have been heavily drawn upon during the period of the "stint" dispute. Another minor dispute at Grimethorpe colliery is awaiting settlement following a short-lived cessation of work by some miners. Allocations of coking coal are on a more satisfactory scale, and the make of coke is improving.

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Welsh Coal Trade.*—During the past week a good deal of opposition has become apparent to the proposal made, and almost unanimously endorsed by a special delegate conference of Welsh miners, to work an additional shift on Saturday mornings on an overtime basis. The delegates recommended the lodges to adopt a uniform plan of working the extra hours called for on Saturday mornings and suggested that the shift should extend from 6 a.m., an hour earlier than on normal days, to 12.30 p.m., so as to give the men an opportunity of taking part in cultural and recreational activities. Before the introduction of the five-day week, the Saturday morning shift extended from 7 a.m. to 2.30 p.m., and it was felt that a good deal of absenteeism was caused by the fact that the miners could not get away in time to get to afternoon sport. During the past week, eight large lodges in the Maesteg area and those at the Penallta Colliery, Rhymney Valley, and the Windsor Colliery, Aber Valley, have rejected the conference recommendations. During the week there have been two strikes at collieries in the Monmouthshire area. The first involved 750 men at the Wyllie Pit in the Tredegar Valley, and concerned the stoppage of bonus pay to five workmen who did not put in the full shifts. The men returned to work on the understanding that the dispute was to be discussed. About 1,600 men employed at the Arrail Griffin Colliery, near Abertillery, came out on strike because they alleged that the management was applying the five-day week conditions too strictly. Trading on the steam-coal market has been very severely checked by the shortage of supplies. Although outputs have continued to show steady expansion, there was barely sufficient coal to cover existing contract commitments for the home market, and, as a result, few fresh orders could be entertained for early delivery. As a rule, order books were well filled for some time ahead, and no easing in the position seems likely for a long time. Exports were impossible except for the limited quantities made available for special consumers in Eire and Canada.

*Swansea Steel-Sheet Industry.*—The market report issued by the Incorporated Swansea Exchange states that, last week, business in tin-plate remained moderately active. The demand was maintained and the volume of business transacted was divided between home and export buyers. In the export market there has been no relaxation in the demand and a fair number of orders has been placed. Steel sheets continue in exceptionally strong demand, which is very much in excess of capacity and makers are inundated with orders. Iron and steel scrap is in stronger demand and consumers are eager buyers of the better classes.

## NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

SOCIETY OF ENGINEERS.—Monday, November 3, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Industrial Organisation and Production," by Mr. R. C. Smart.

INSTITUTION OF ELECTRICAL ENGINEERS.—*South Midland Centre:* Monday, November 3, 6 p.m., James Watt Institute, Birmingham, "Electric Traction on the Southern Railway," by Mr. C. M. Cock. *Mersey Centre:* Monday, November 3, 6.30 p.m., Royal Institution, Colquitt-street, Liverpool. "Elements of Position Control," by Prof. K. A. Hayes. *North-Western Centre:* Tuesday, November 4, 6 p.m., Engineers' Club, Manchester. "Neutral Earthing of Three-Phase Systems," by Messrs. J. R. Mortlock and C. M. Dobson. *East Midland Centre:* Tuesday, November 4, 6.30 p.m., Loughborough College. "Electrical Machine Design," by Mr. L. H. A. Carr. *London Students:* Tuesday, November 4, 7 p.m., Victoria-embankment, W.C.2. Problems Night. *Radio Section:* Wednesday, November 5, 5.30 p.m., Victoria-embankment, W.C.2. "Tests of Components for Broadcast Receivers," by Dr. G. D. Reynolds. *Institution:* Thursday, November 6, 5.30 p.m., Victoria-embankment, W.C.2. "Electric Traction on the Southern Railway," by Mr. C. M. Cock. *Measurements Section:* Friday, November 7, 5.30 p.m., Victoria-embankment, W.C.2. Discussion on "Telephone Cable Measurements," opened by Mr. S. Hanford.

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, November 4, 5.30 p.m., Great George-street, S.W.1. Presidential Address, by Sir Roger Hetherington, C.B. *South Wales Association:* Tuesday, November 4, 6 p.m., Institute of Engineers, Park-place, Cardiff. Chairman's Address by Major W. W. Marsden. *Newcastle-upon-Tyne Association:* Tuesday, November 4, 6.15 p.m., Neville Hall, Newcastle-upon-Tyne. "Modern Developments in Air Survey," by Dr. A. M. Ballantyne. *Birmingham Association:* Friday, November 7, 6.30 p.m., Midland Institute, Paradise-street, Birmingham. Joint Meeting with INSTITUTION OF MECHANICAL ENGINEERS (*Midland Branch*) and INSTITUTION OF ELECTRICAL ENGINEERS (*South Midland Centre*). "District Heating," by Mr. A. E. Margolis.

CHEMICAL ENGINEERING GROUP.—Tuesday, November 4, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Stainless Steels for Chemical Engineering." by Mr. L. Rotherham.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, November 4, 6.30 p.m., 39, Elmbank-crescent, Glasgow. "Steel Processing," by Messrs. J. A. Kilby and W. G. Cameron.

JUNIOR INSTITUTION OF ENGINEERS.—*Western Group:* Tuesday, November 4, 7.30 p.m., Technical College, Bath. "Fatigue of Metals," by Dr. H. P. Badgen. *Midland Section:* Wednesday, November 5, 7 p.m., James Watt Institute, Birmingham. Chairman's Address, by Mr. L. Hunt. *Institution:* Friday, November 7, 6.30 p.m., 39, Victoria-street, S.W.1. "Sir Hiram Maxim," by Dr. A. P. Thurston.

INSTITUTE OF FUEL.—Wednesday, November 5, 2.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. "Coal Resources," by Mr. D. Hicks.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—Wednesday, November 5, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "District Heating," by Mr. D. V. H. Smith.

INSTITUTION OF MECHANICAL ENGINEERS.—*London Graduates:* Wednesday, November 5, 6.30 p.m., Storey's-gate, S.W.1. "Transmission," by Mr. B. Bramall. *North-Western Branch:* Thursday, November 6, 6.45 p.m., Engineers' Club, Manchester. "Pressure Vessel of Laminar Construction," by Messrs. H. Birchall and G. F. Lake. *Institution:* Friday, November 7, 5.30 p.m., Storey's-gate, S.W.1. "Measurement of Temperature of Sliding Surfaces, Especially Railway Brake Blocks," by Drs. R. C. Parker and P. R. Marshall. AUTOMOBILE DIVISION. *London:* Tuesday, November 4, 6 p.m., Storey's-gate, S.W.1. "Independent Suspension," by Mr. M. A. Jullien. And at *North-Eastern Centre:* Wednesday, November 5, 7.30 p.m., University, Leeds. And at *Birmingham Centre:* Thursday, November 6, 6.30 p.m., Imperial Hotel, Birmingham.

ROYAL SOCIETY.—Thursday, November 6, 4.30 p.m., Burlington House, Piccadilly, W.1. Bakerian Lecture on "Problems in Connection with the Development of a High-Speed Diesel Engine," by Dr. H. R. Ricardo, F.R.S.

ROYAL AERONAUTICAL SOCIETY.—Thursday, November 6, 6 p.m., Institution of Civil Engineers, Great George-street, S.W.1. "Developments in Landing Gear," by Capt. R. Lucien.

ROYAL INSTITUTION.—Friday, November 7, 9 p.m., 21, Albemarle-street, W.1. "Foam," by Prof. E. K. Rideal, F.R.S.

# 32-MW TURBO-ALTERNATOR SET AT WILLESDEN GENERATING STATION.

MESSRS. ENGLISH ELECTRIC COMPANY, LIMITED, LONDON.

(*For Description, see Page* 417.)

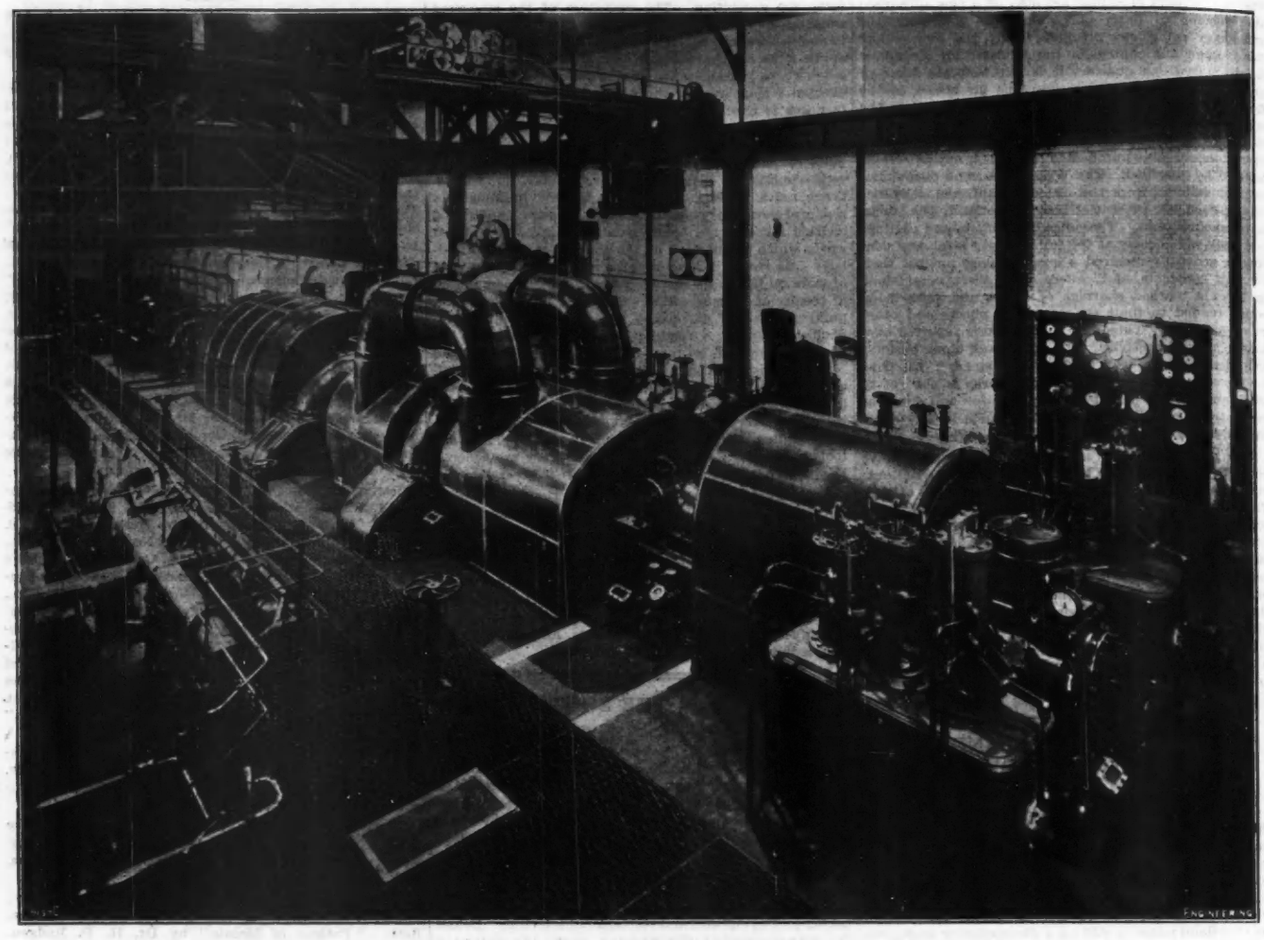

Fig. 3. View of Set from Steam End.

## UNIVERSITY COLLEGE, SOUTHAMPTON, SCHOOL OF NAVIGATION.

Mention was made, on page 376, *ante*, of a visit paid by members of the Institution of Naval Architects to the School of Navigation at Warsash, during the recent autumn meeting of the Institution. We have since received from the Director, Captain G. W. Wakeford, particulars of the courses provided by the School, both for cadets and to qualify officers of the mercantile marine, yachtmasters, and civil air pilots. The cadets' course is designed to meet the requirements of boys who intend to make the sea their career, with a view to becoming officers in the merchant service. It consists of 40 weeks' instruction, divided into three terms, and may start at the beginning of any term; the next term will begin on January 16, 1948. The syllabus is in three parts, comprising, respectively, academic subjects, professional subjects, and practical subjects. The course is recognised and approved by the Ministry of Transport and the Ministry of Education, and cadets who secured a certificate of efficiency obtain remission of six months of the four years of qualifying sea service required of candidates for a certificate of competency as second mate. The age of entry is between 16 years and 16 years 8 months. Various scholarships and bursaries are available.

The senior courses available at the School cover the educational requirements for certificates of competency as second mate, first mate, master, extra master; the corresponding coastal-trade certificates; yachtmasters' certificates, foreign-going and coastal; and the compass adjuster's certificate. Preparatory postal courses are also conducted in certain subjects. Classes in civil air navigation are provided to cover air navigators' licences of all standards and the civil pilot's licence, Class B. Further particulars are obtainable from the Director, School of Navigation, Warsash, near Southampton.

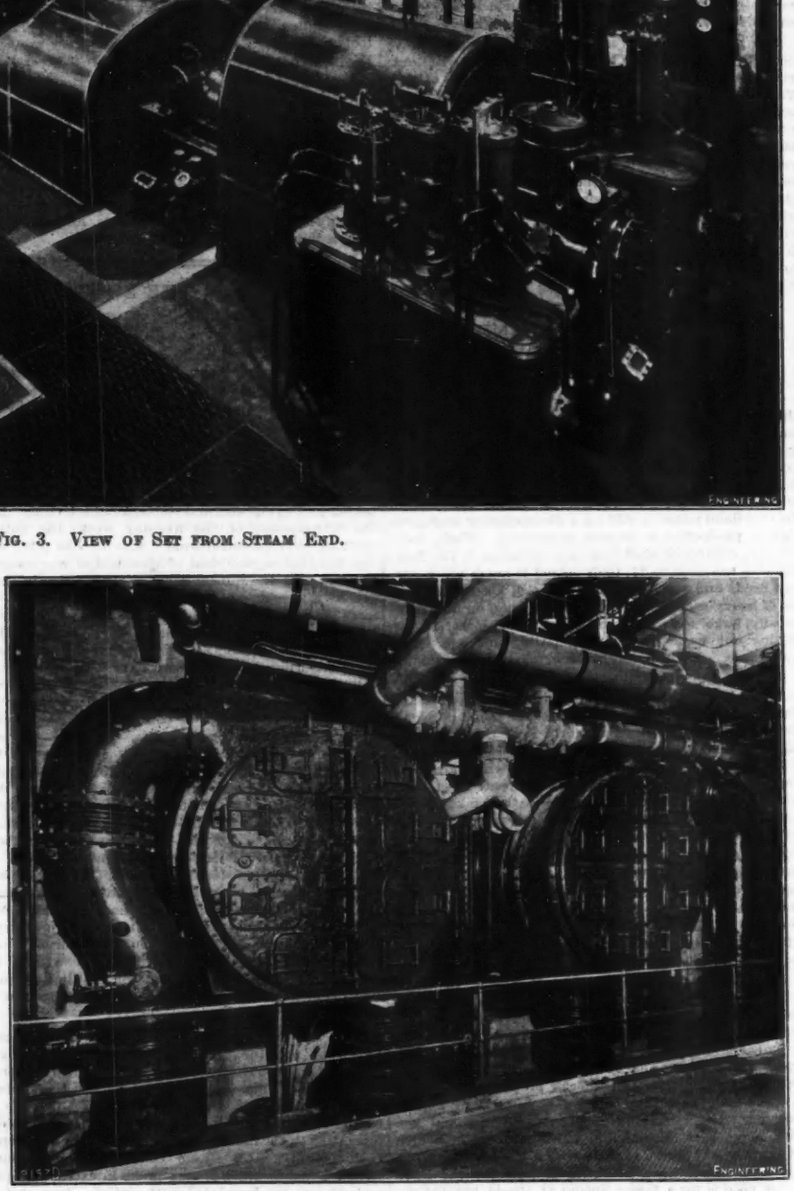

Fig. 4. Surface-Condensing Plant.

# ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

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## TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.


## INDEX TO VOL. 163.

**The Index to Vol. 163 of ENGINEERING (January-June, 1947) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher. In order to reduce the consumption of paper, copies of the Index are being distributed only in response to such applications.**

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# ENGINEERING

*FRIDAY, OCTOBER 31, 1947.*

VOL. 164. No. 4266.


## ENGINEERS AND SOCIETY.

As a change from the contemplation of the state of the nation after two exhausting wars, it is instructive and not wholly discouraging to reconsider, even cursorily, that important social movement commonly called the Industrial Revolution, which started in this country just about two centuries ago. To do so is to realise some aspects that rarely receive the emphasis they deserve. Prominent among them is the historical fact that the revolution was primarily the work of engineers. The third quarter of the Eighteenth Century saw, in turn, the use of coal for smelting iron, the transformation of the steam engine into a seemingly inexhaustible source of industrial power, the improvements in textile machinery culminating in the invention of the power loom, and the introduction of bulk transport by inland waterways. Throughout the ensuing 150 years, as railways, steamships, electric power, internal-combustion engines and aircraft accelerated the pace of mechanical civilisation, the influence of engineering upon material prosperity steadily increased and to-day shows no sign of having yet reached its peak. The Industrial Revolution was not so much an isolated event, therefore, as the start of a process in the course of which some vitally important changes affecting engineers have taken place and are still in progress.

The outstanding engineers of the past—sturdy individualists to a man—were themselves the founders of industries that started on lines not essentially different from those manned by the individual craftsmen they were superseding. Less than a generation was needed, however, to reveal the tendency towards concentration in industry, which in retrospect appears to be the inevitable consequence of the change from hand tools to large machines and the rise of the factory system. It led to the supersession of the small manufacturer, first by the modest, and later by the not so modest, capitalist. In turn, the individual capitalist was absorbed in the company or the municipal undertaking, both of which have tended to be themselves combined in corporations of international dimensions, or in nationally sponsored and controlled organisations. In so far as this progression is inherent in industry, completely international direction and globally organised control of production and all major sources of power is to be expected ultimately, with State ownership as the present intermediate stage, already developed to varying degrees in several parts of the world.

The profound changes in human society that have accompanied the growth of mechanical civilisation, and, to a large extent, are to be regarded as the consequences of it, have tended, on the whole, towards reduction to a common economic level. Contrasts of private wealth and poverty, and of personal power and dependence, are diminishing visibly; and, although income is still the most widely accepted basis of social stratification, the sources of income are markedly different to-day from what they were before, and during, the early part of the Industrial Revolution. In particular, the expansion of professional engineering has taken place very largely during the ensuing period; and, since its rate of growth is at present more rapid than ever before, and is being fostered in this country, as well as in others, in pursuit of certain aspects of national policy, the time is opportune to re-examine the existing and prospective status of engineers in society. For this purpose, it is legitimate to regard professional engineering as comprising all branches of technology concerned with the application of scientific discovery to practical use. To do so is to realise at once what a large proportion of higher education is directed solely to this purpose, and how important is the part played by the work of engineers both now and in the past.

On these grounds it would not be unreasonable to infer that engineers ought to be the most powerful group in the whole of modern society. The facts that they are not, that many of them do not wish to exercise power, and that some are not fitted to do so, are evidently related closely to the causes underlying the social standing of engineers, and emphasise the distinction between the engineer and the results of his work. The course of industrial development, previously outlined, shows how the control of engineering products has passed from the individual engineer to the factory owner, the company or the State. More and more, the author of creative work has become the employee of another, subordinate as regards the disposal of his inventions and developments, and consequently inferior in exerting social influence. The "engineer" is indeed "hoist with his own petard," since it was he who inaugurated and promoted the system of which he is already the victim. The recent growth of research organisations and State-sponsored projects employing large numbers of applied scientists introduces differences of detail, but points, if anything, to a diminishing social influence, if only because numerically large staffs lend themselves to treatment as statistical units and groups rather than as individuals.

From another standpoint, this increase in the mere number of qualified technical workers appears to offer opportunities for self-organisation along lines similar to those of a trade union. At least two such bodies have existed, in fact, for several years, and their growth of membership is no doubt among the factors which, from time to time, encourage proposals for guilds of engineers, recognition of qualifications for professional practice, and greater political activity on the part of the engineering and kindred institutions. The reasons why such forms of organisation rarely arouse the spontaneous universal enthusiasm that they merit in the eyes of their promoters warrant really serious study, if only because of the admitted importance of applied science to the future of civilisation. It is, for example, by no means a matter of course that the preoccupation of mankind with physical and material things represents progress rather than retrogression, or that the actual historical sequence of the technician's status in society since the Industrial Revolution has been either inevitable or wholly desirable. In some measure, however, the answer to these immense questions, as well as to the smaller and more immediate ones, must be sought in the characteristics of engineers and applied scientists, particularly with respect to the differences between them and those of other men, and to the generally accepted criteria of effectiveness in society.

A recent American book entitled *The Engineer in Society** advances some thoughtful and challenging

* *The Engineer in Society.* By John Mills. D. Van Nostrand Company, Incorporated, 250, Fourth-avenue, New York 3, U.S.A. [Price 2.50 dols.]; and Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 14*s.* net.]

observations bearing on this subject. The author, Mr. John Mills, is a trained electrical engineer who spent the mature years of an interesting career as personnel officer for the Bell Telephone Research Laboratories. He is consequently qualified to view the present status of engineering from the inside, illuminated by the clear light of factual experience, and to support some provocative and forthright conclusions by arguments that are plausible, if not always comprehensive or wholly convincing. He is in no doubt whatever that engineers are too modest of their great traditions and modern accomplishments, and that they will not get the chance to show what they can do in the way of directing the course of political events and moral developments unless they reach out and seize it. He would have them apply the objective methods of science to the things that affect their lives and material surroundings, seeking truth and presenting it persuasively to their fellow men without regard to what are known as vested interests. He disagrees with those who think that modern civilisation is based on the economic motive and that engineers and creative thinkers generally are "a dime a dozen" in the hands of commercial magnates.

It is a little difficult to reconcile the achievement of so dominant a position in human affairs with the existing personal characteristics of the average technical man, who, on Mr. Mills's own showing, is primarily interested in ideas and things, with men and economic symbols following in that order. He is concerned, in other words, rather with his work than with what he is paid for it; more with discovering and making use of his discoveries than with the rest of mankind, who, incidentally, benefit by what he discovers and makes. Himself a type whose work is a vocation, a sufficient objective in itself, he gets little satisfaction out of a sense of power over others, is intolerant of regimentation for himself, and is at his best among a team of equals all imbued with like motives. Such characteristics are the very antithesis of what makes for personal leadership based largely on emotional appeal, as exemplified in outstanding figures of history, both famous and infamous. Even within the restricted sphere of the mechanical sciences, it is commonly the fact that seniority in an organisation leads to an increasing proportion of purely administrative duties until creative scientific work is crowded out altogether. It is probably very near the truth to say that almost all the occupants of important posts in the engineering profession to-day are preoccupied more with problems of human relationships than with technical matters.

The implications seem clear enough. Natural phenomena and material things are hard enough to understand, but human beings with individualities, free wills and moral attributes are as much more difficult as they are superior to material things. Inasmuch as influence in society demands knowledge of social and political affairs, it is not to be gained by knowledge of engineering alone, or by the erudite specialisation needed for a prominent position on the advancing front of scientific discovery. Only by subordinating himself and his work to a recognised high purpose; by becoming first conscious of his influence in social affairs and then striving with equally conscious determination to be sure that his influence is, beyond all possibility of mistake, for good; and, finally, by being prepared to make any reasonable sacrifice in ways of living, thinking and working—only by some such changes of heart and mind will applied scientists succeed in making the force of what they are doing fully felt by those for whom they are doing it.

The only alternative is such a change of heart on the part of the rest of the world as would freely give to engineers the appreciation, the rewards and the control over their own creations that they deserve. Perhaps it is not altogether a bad thing that, no such change of heart being evident, the engineer looks like having to make his own track up the slope of recognition. He will learn a good deal about himself and his fellow men on the way, and the knowledge cannot fail to be of tremendous importance in an epoch when the exploitation of atomic energy for power production may bring about industrial changes more revolutionary than those of 200 years ago.

## ELECTRICITY SUPPLY IN ONTARIO.

During the war, especially during the final two years of it, electricity-supply undertakings had to operate with little or no margin of surplus capacity, and major maintenance work had to be postponed, but throughout the period sufficient power was made available for essential domestic and manufacturing purposes by means of Government restrictions and voluntary economies by consumers. It was anticipated in some quarters that, for at least a limited period after the termination of hostilities, the total demand for power would be less, owing to cessation of the manufacture of war equipment. This expectation has not been realised and in the winter season, 1946-47, it was again necessary to instruct consumers to restrict their demands as far as possible. These remarks, which may appear to refer to Great Britain, are actually an abstract of paragraphs appearing in the Thirty-Ninth Annual Report of the Hydro-Electric Power Commission of Ontario. As is only too well realised, conditions in Great Britain and Canada are very different at the present time, but it is of interest, and may be of some comfort, to know that in the sphere of electricity supply the two countries are experiencing similar difficulties.

The report is naturally confined to conditions in Ontario, but it is stated that economies and modifications in supply arrangements practised in the Province during the war were imposed in "other parts of Canada" and it is probable that in broad outline the report describes a situation common throughout the country. It would not be profitable to deal in detail with the comparative aspects of electricity supply in Great Britain and Canada, but there is one item in the overall picture which is favourable to the latter, and which had much influence in enabling supplies to be maintained over a period during which the combined peak loads on all the systems of the Commission increased from 2,050,000 h.p. in December, 1939, to 2,600,000 h.p. in July, 1945. This item, which is missing in Great Britain, represents the demand for "secondary power," which may be taken as the equivalent of what would be described as off-peak power in this country. Secondary power is mainly supplied to the pulp and paper industries for the operation of electric boilers, and by restricting the activities of this branch of manufacture, large blocks of power became available for purposes more directly concerned with the prosecution of the war.

The report covers the year ended October 31, 1946. The maximum peak during the period covered was 2,625,000 h.p., which is 17,000 h.p. greater than the maximum peak of the previous year. The energy output from generated and purchased sources was 12,672,017,312 kWh, which exceeded that of the previous twelve months by 1·5 per cent. Although the primary power peak exceeded by 1·8 per cent. the highest level of the war years, the primary-power energy decreased by 1·4 per cent., compared with 1945. This effect was entirely due to temporary cessation of demands due to labour disputes. By far the most important part of the area served by the Commission is covered by what is known as the Southern Ontario system, which includes such large towns as Toronto and Hamilton. It is on this system that the major industrial load falls, and the growth in demand, coupled with the effect of deferred maintenance and construction, had the result that during the winter of 1946-47 large industrial users who purchased power on an "interruptible" basis had frequently to be cut off. "To these customers the power shortage was very real and serious." One result of war-time manufacturing developments in this area is that new industries not previously represented in the Province are being started. It is added that "branch plants of British concerns are being established in many municipalities."

The total area served by the Commission is divided, for both administrative and technical reasons, into the Southern Ontario System, the Thunder Bay System, and the Northern Ontario Properties. The second of these covers the district around Lake Nipigon and includes the towns of Port Arthur and Fort William, situated on Lake Superior. There are many paper companies in Port Arthur and the energy supplied to this system increased by 11·5 per cent. as compared with the previous year. Secondary energy, mainly used in electric boilers, amounted to 120,123,300 kWh. The Northern Ontario Properties, which comprise a number of districts not all electrically-connected, are administered by the Commission in trust for the Province. The main industrial activity of the Properties is represented by mining enterprises, but agriculture is increasing in importance. During the year covered by the report, 14 mining consumers were either supplied for the first time, or had supplies restored which had been interrupted during the war. The peak horse-power for the Properties as a whole increased by 6·6 per cent.

Agriculture constitutes one of the most important activities in Ontario and the rural electrical service conducted by the Commission is an important factor in its general prosperity. The extent of this service is illustrated by the fact that the total number of consumers served exceeds the total numbers in all the cities of the Province, except for the four that have populations exceeding 100,000. The average load per rural consumer is necessarily relatively small, which adds to the difficulty of conducting a service of this kind on an economic basis. In view of its importance, it is assisted by Government grants. Of the capital investment in transmission lines and other facilities necessary for the rural services, amounting to 45,000,000 dols., nearly half is represented by Government grants in aid. At the end of 1946, the total mileage of rural lines constructed, or under construction, was 23,700. These serve, or will shortly serve, 178,000 consumers; the aggregate peak load last winter at times exceeded 165,000 h.p.

Comparison with conditions in Great Britain is once more suggested by the difficulty which is being experienced in obtaining material for line extensions. On October 31, 1946, there were enough applications for rural service to justify the construction of 4,559 miles of additional primary line, and it is anticipated that applications in the course of this year will increase the figure to 7,529 miles. Constructional plans, however, cover only 1,500 miles and no certainty is felt that even this limited programme will be carried out. Supplies of wood poles have become more satisfactory since the end of the war, but conductor material, line fittings and transformers are still impossible to obtain in adequate quantity. The whole situation has been rendered more difficult by the fact that in the interests of food production during the war, any material available was used for extensions rather than for the improvement of existing services.

It was not only in the extension of transmission and distribution lines that work had to be deferred during the war. The same thing applied to generating plant, with the result that the power-station work now in hand is much greater than for many years past. There are four major projects in progress which, with the installation of a fourth unit in the Ear Falls station, which serves part of the Northern Ontario Properties, will increase the total generating capacity by 575,000 h.p. Of the four major new works or extensions, three will serve the Southern Ontario System and one, the Thunder Bay System. This latter covers the construction of a station on the Aguasabon River where it discharges into Lake Superior; it will contain two 27,500-h.p. generating units. The Southern Ontario System developments comprise the extension of the DeCew Falls Station by the installation of a second 65,000-h.p. set. Civil engineering work in connection with this extension has been in hand for some years. The plant is expected to be in operation this year. A new station is being built at Stewartville on the Madawaska River, about ten miles from the point where it joins the Ottawa River. The work involves the construction of a concrete dam 200 ft. high and 850 ft. long. The station will have a capacity of 81,000 h.p. and is expected to be ready next year. The third development is not so far advanced and its first section will not be available before 1950. It consists of a new station at Des Joachims on the Ottawa River, where six units, totalling 360,000 h.p., will be installed initially.

# NOTES.

### INSTITUTION OF MECHANICAL ENGINEERS.

LORD DUDLEY GORDON, D.S.O., delivered his presidential address to the Institution of Mechanical Engineers at a general meeting held at Storey's-gate, St. James's Park, London, S.W.1, on Friday, October 24, 1947. He reviewed the development of two branches of engineering with which he has been associated, namely, the iron and steel industry, and the manufacture of refrigerating machinery; and drew attention particularly to the work of members of the Institution in these fields, as recorded in the *Proceedings*. There were many famous names in the list of past presidents and vice-presidents, he said, associated with advances in the iron and steel industry, and those men had often achieved valuable results without the help of scientific theory, which was usually propounded some time afterwards. Siemens, Bessemer, Whitworth, Vickers, Hadfield, Roberts-Austen, and Wicksteed were some of the notable members to whose work Lord Dudley Gordon referred. The practice of refrigeration was comparatively recent, he continued, although Jacob Perkins had demonstrated the practicability of a refrigerating machine in 1834. The subject was first brought to the notice of the Institution by T. B. Lightfoot in 1881, and the growth of the industry since then had been considerable. The President showed two cinematograph films, one dealing with each of his topics, and illustrating present-day practice. Major William Gregson, M.Sc., vice-president, proposed a vote of thanks to the President for his address, and Dr. H. J. Gough, C.B., M.B.E., D.Sc., F.R.S., vice-president, seconded the proposal, which was carried by acclamation. During the course of the meeting it was announced that the late Sir Leonard Pearce, C.B.E., D.Sc., had been elected an honorary member shortly before his death, which had occurred on October 20, 1947; members stood for a moment in remembrance. Dr. Arthur Morley, O.B.E., D.Sc., Wh.Ex., has also been elected an honorary member. Engineer Vice-Admiral D. C. Ford, C.B., C.B.E., and Major-General W. S. Tope, C.B., C.B.E., have been appointed to fill vacancies in the Council caused by the retirement of Engineer Vice-Admiral Sir John Kingcome, K.C.B., and Major-General Sir Bertram Rowcroft, K.B.E., C.B.

### CODES OF PRACTICE FOR THE ELECTRICAL EQUIPMENT OF BUILDINGS.

The Codes of Practice Committee for the Electrical Equipment of Buildings, which was convened by the Council of the Institution of Electrical Engineers on behalf of the Independent Codes of Practice Committee, has undertaken work on 26 Codes of Practice, so far, covering various aspects of electrical installation work. Of these codes, eleven have already been promulgated publicly as drafts for comment, and it may therefore be interesting to record the stages through which they have to pass before publication in final form. The Electrical Codes of Practice Committee, having agreed that the preparation of a particular code is desirable, appoints a small sub-committee to make a draft. This draft is submitted to the parent committee, who consider not only its content, but its relationship to the other codes for which they are responsible. It is then transmitted to the Engineering Services Sectional Committee of the Independent Codes of Practice Committee, who scrutinise it particularly in relation to the other codes which deal with the provision of engineering services in buildings. The code, with any amendments that have been made, is then printed and placed on sale by the British Standards Institution as a draft for comment. Forty days are allowed for interested organisations or persons to make their views known; and that this is no mere formality is shown by the fact that 477 comments were received regarding the draft code on Electrical Installations (General). The collation of these comments is now undertaken by the Institution of Electrical Engineers and the results are reviewed by the sub-committee, which was responsible for the preparation of the original draft. Amendments are introduced to give effect to the comments which are supported, while note is taken of the reasons which have led the sub-committee to reject the others. The amended code, with this note, then goes successively before the Electrical Code Committee and the Engineering Services Sectional Committee who, if thought fit, recommend to the Independent Code of Practices Committee that it be published in final form as a British Standard Code of Practice. The question has often been raised as to the relationship between the Codes of Practice and the Regulations for the Electrical Equipment of Buildings, published by the Institution of Electrical Engineers and commonly known as "The Wiring Regulations." The position is that while the Wiring Regulations may be regarded as setting out the minimum safety requirements, the Codes of Practice go farther in their encouragement of good practice and may well recommend the adoption of methods showing some improvement over those regulations in points of detail. On the other hand, the Codes of Practice never recommend a practice which would be inadmissible under the Regulations.

### TESTING DOMESTIC HEATING APPLIANCES.

It is announced by the Department of Scientific and Industrial Research that a substation of the Fuel Research Station at Greenwich is to be set up in Scotland. This station will be concerned primarily with the testing of domestic heating appliances, which is appropriate, since about half of that type of equipment, burning solid fuel, is made in Scotland. It may be recalled that the main Fuel Appliance Testing Station is at Greenwich, where a large number of tests are carried out on behalf of an inter-departmental committee on which the Ministries of Fuel and Power, Health, Supply and Works are represented. The appliances are tested in accordance with procedures, and up to standards, mutually agreed between those Ministries and the manufacturers. Those appliances which are approved are then placed on an "approved list," which is circulated to all the local authorities in Great Britain. The object of the tests made at this station is to get better appliances and not merely to reject those which are unsatisfactory. The testers, therefore, keep closely in touch with the manufacturers while investigations are going on, with the result that it is often possible for the latter to make improvements.

### THE SCOTTISH SEAWEED RESEARCH ASSOCIATION.

A survey by the Scottish Seaweed Research Association, commenced in April, 1945, and concluded in December, 1946, which covered 4,250 miles, or 92 per cent. of the practicable Scottish coast, excluding the Shetland Islands, showed that 12 per cent. of the whole supported a littoral seaweed growth of more than 100 tons of seaweed per mile; none of this length lay on the east coast. An independent survey of sub-littoral weed showed the existence of extensive quantities amounting, for instance, to 45,000 tons in the Bay of Firth and 13,000 tons in Scapa Flow. Cast weed represents another source of supply, and a further survey conducted by the Scottish Agricultural Organisation Society, had indicated the presence of 120,600 tons of cast weed on the beaches under observation. The activities of the Scottish Seaweed Research Association are directed to the possible economic uses of seaweed. Possible applications of the weed are matters for chemical and physical investigation, but recovery and harvesting must take first place if commercial exploitation is to be established on an important scale. These latter operations constitute mechanical problems and are dealt with by the Engineering Division of the Association. It is stated in the Annual Report for 1946 that "the problems facing this Division are among the most important, and at the same time the most difficult to solve." For harvesting littoral weed, cutting with a serrated hand sickle has shown an average cutting rate of 9·5 cwt. per man-hour. Attempts have been made to harvest sub-littoral weed by the entrainment in water of weed previously cut by submarine rotating cutters, but have not been successful. The problem is still under examination. Drying of the recovered weed is also an important mechanical problem; seven methods have been tried and the old and conventional way of spreading it on the ground and turning it at intervals has been found the most inefficient of all. The most successful method employed back-to-back inclined grids over which the seaweed was spread. About 24 hours were necessary to dry to a 50 per cent. moisture content. Mechanical drying with a Dunford and Elliott rotary louvre hot-air plant has been tried, but no comparative costs are given in the report. The business of the Chemistry Division of the Association is to determine the chemical composition of the weeds and the extent to which it varies between different species and with season, age and environment. In this way data may be established from which methods of using derivatives and technical value may be developed. The main work so far has been carried out on brown algæ, particularly various species of *Fucus* and *Laminaria*, which will be known to most non-botanical readers as bladder rack and strap weed. The main constituents are ash, iodine, nitrogen, mannitol and alginic acid. Apart from the exploitation of seaweed for the separation of some of the chemical compounds which it contains, experiments are being made on its use as a component of animal foodstuffs, the first work being done with sheep. A further possible use is as a soil fertiliser, for which purpose it is at present employed locally where it is abundant and easy of access.

### THE NORTH-EAST COAST INSTITUTION.

The annual report of the Council of the North-East Coast Institution of Engineers and Shipbuilders for the 63rd session (1946-7) records, *inter alia*, various proposed changes in the constitution of the Council, involving amendments to the articles of association. These provide that the number of vice-presidents shall not exceed eight, and that their term of office shall be eight years, one vice-president retiring in each year. The number of ordinary members of Council would be increased to 24, with a term of office of four years, six members of Council retiring each year; and four of the Council would be associates of the Institution. It is also proposed that retiring vice-presidents shall be eligible immediately for re-election. The necessary changes in the articles are to be submitted as a special resolution at a special general meeting this evening (October 31). Among other matters dealt with in the report is that of the new measured mile at Newbiggin. The marking towers were completed before the end of the session, except for the topmast of one tower, and the new mile is already in use for trials; but it has not been possible as yet to fit the lighting equipment. A preliminary *Chart and Table of Speeds* has been prepared and issued to North-East Coast shipbuilding and engineering firms; copies may be obtained from the secretary of the Institution. The old Hartley mile posts have been entirely dismantled. A proposal to use radar methods of checking speeds on measured-mile trials was considered by the Council and was referred by them to the British Shipbuilding Research Association; a suitable instrument for the purpose is being developed. The awards for papers were as follows: The Institution Engineering Medal to Dr. S. F. Dorey, C.B.E., and Mr. G. H. Forsyth, M.Sc., for their paper on "Some Gear-Cutting Inaccuracies and their Effect on Gear Loads and Gear Noises"; the Institution Shipbuilding Medal to Mr. R. B. Shepheard, B.Sc., and Mr. F. B. Bull, B.Sc., for their paper on "Structural Investigations in Still Water on the Tanker Newcombia"; and the M. C. James Medal to Mr. A. W. Davis, B.Sc., for his paper on "The Application of the Reheat Steam Cycle to Marine Propulsion, with special reference to the C.P.R. 'Beaver'-class Turbo-Electric Cargo Liners." No award was made of the Institution Scholarship, but the 1946 award, to Mr. E. V. Lockney was renewed to enable him to study for an honours degree. Mr. Lockney was also the first recipient of the Scholars' Scholarship, founded in 1943 by a group of former Institution Scholars. The Weighton Medal for 1947 was awarded to Mr. D. J. Doust, and the Thomas Fenwick Reed Medal to Mr. Adam Mitchell. The membership of 1,870 includes two new Fellows, Mr. P. B. Johnson and Mr. George H. Wright, O.B.E.

# OBITUARY.

## SIR LEONARD PEARCE, C.B.E., D.Sc.

Sir Leonard Pearce, whose death, as briefly announced in our previous issue, occurred at Bickley, Kent, on October 20, at the age of 74, was highly esteemed among engineers as a designer of high-efficiency power stations and as a pioneer in the development of many advances in their equipment. To a much wider circle he was, much against his will, equally well known as a participant in controversies over the siting and potential nuisance of these plants. It is well, therefore, that any notice of his career should put on record the fact that practice has proved his ideas to be fully justified.

Standen Leonard Pearce was born at Crewkerne, Somerset, on September 28, 1873, and was educated at Bishop's Stortford and at Finsbury Technical College. Subsequently, he was apprenticed to J. G. Statter and Company, Limited, West Drayton, and then was engaged for a time in the works and drawing office of Thomas Richardson and Sons, Hartlepool. After serving for a short time at sea with the British India Steam Navigation Company, he became assistant engineer to the Metropolitan Electric Supply Company and, in 1899, joined the staff of the British Thomson-Houston Company, who were then engaged on the equipment of the Central London Railway with generating and substation plant. On the completion of their contract he became superintendent engineer at the power station of the railway at Shepherd's Bush, but relinquished this position in 1901 on his appointment as deputy chief electrical engineer of the Manchester Corporation. In 1903 he became chief electrical engineer to the Corporation; and held that position until his appointment as Electricity Commissioner in 1925. During this time he designed the power station at Barton, the first section of which had an installed capacity of 82·5 MW. This station soon exemplified the soundness of its design by becoming the most economical in the country in respect of coal consumption. It was afterwards extended in accordance with his ideas to its present capacity of 178 MW. He was also concerned, during the 1914-18 war, with the formation of a committee to conserve the coal resources of Lancashire and Cheshire and to co-ordinate the supply of electricity in the two counties. In 1920, he was largely responsible for the preparation of the South-East Lancashire Electricity Scheme and acted as chairman of the Advisory Board in that area. In 1924, he visited Australia to advise the Governments of New South Wales and Victoria and the Corporation of Sydney on electricity supply.

After a year as Electricity Commissioner, during which he did a great deal to formulate the national transmission scheme which was embodied in the Electricity (Supply) Act, 1926, Pearce accepted the position of engineer-in-chief of the London Power Company. This step gave rise to a certain amount of comment, some critics considering it inappropriate that an official who had once been entrusted with the secrets of Government policy should return to private work. It is no secret, however, that he preferred the technical side of engineering to the administrative, and, in any event, his services were particularly required at that time to co-ordinate the supply of electricity in that large area of the capital which came under the control of the London Power Company. An essential part of the scheme he prepared for this purpose was the provision of a large station near the centre of the west-end load. When, however, it was known that a site at Battersea had been selected, an outcry arose on the grounds that the fumes would not only cause a nuisance, but would damage such historic buildings as Westminster Abbey. It was urged that the proper place for such a station was much lower down the river. The impracticability of the latter suggestion was soon made clear, however, while events have since proved that the installation of the gas-washing plant which was designed under Pearce's direction has completely obviated the risk of damage. The question of atmospheric pollution also arose in connection with the Barton station; and, more recently, Pearce was involved to some extent in another siting controversy when, in the spring of this year, protests were made against the proposal to erect a large station at Bankside, opposite St. Paul's Cathedral. He again became a part-time Electricity Commissioner from 1940 to 1945, but in the latter year he was appointed the chief executive officer of the London Power Company on the death of the general manager, Mr. W. A. Pearman. He was holding this position at the time of his death. It is a regrettable coincidence that the chairman of the London Power Company, the Rt. Hon. the Earl of Lytton, K.G., died on October 25, only five days after Sir Leonard Pearce.

Sir Leonard was appointed a Commander of the Order of the British Empire in 1919 for his services during the 1914-18 war, and received a knighthood in 1935. He was also an honorary D.Sc. of the University of Manchester, and was an active member of many engineering institutions. He was elected an associate member of the Institution of Civil Engineers in 1900 and was transferred to the class of member in 1909. He was awarded a Watt Gold Medal in 1923 for a paper on the Barton power station, of which he was joint author with Mr. H. W. Allott. At the time of his death he was serving on the Council. His connection with the Institution of Mechanical Engineers began in 1899, when he was elected an associate member, being transferred to the class of member three years later. He was elected to the Council in 1935 and was a vice-president from 1939 until this year. He became an honorary life member in May, 1947. The Thomas Hawksley Lecture which he delivered to this institution in 1940 was reprinted in our 149th volume; of necessity abridged, for it was a most comprehensive and liberally illustrated survey of power-station development as he had witnessed it, and often inspired it, during his professional career. He was elected an associate of the Institution of Electrical Engineers in 1898, becoming an associate member in 1901 and a member in 1904. He had served on the Council and as vice-president of this body and had been chairman of the Manchester Local Section. He was awarded the Faraday Medal this year. He was also a past-president of the North-Western Association of the Institution of Civil Engineers, of the Incorporated Municipal Electrical Association, and of the Junior Institution of Engineers, as well as an honorary member of the American Society of Mechanical Engineers and a member of the American Institute of Electrical Engineers.

A memorial service for Sir Leonard Pearce is to be held at the Westminster Chapel, Buckingham-gate, London, S.W.1, at noon on November 4.

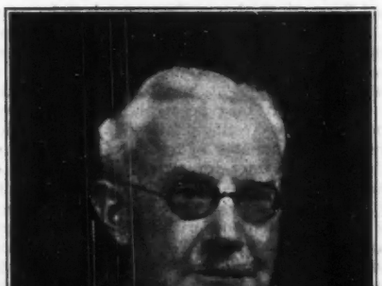


*Photo: Elliott & Fry, Ltd.*

The Late Sir Leonard Pearce, C.B.E., D.Sc.

# LETTERS TO THE EDITOR.

## THE MEANING OF MASS.

To the Editor of Engineering.

Sir,—Having just read Mr. C. Hubert Plant's letter in your issue of October 3, page 327, may I make some suggestions on this very interesting and fundamental matter? As a definition of "mass" I would propose "That common property of matter by virtue of which it exhibits the phenomena of inertia and gravitational attraction;" and of Inertia: "The phenomenon of reaction to change of state of motion." Of material bodies the experimental relationship between the measures of inertia and gravitational attraction shows uniform proportionality.

A concentration of energy has been shown to exhibit the phenomenon of additional inertia proportional to the amount of energy. It has therefore one of the attributes of "mass." I am not clear whether it has also been factually demonstrated to exhibit the phenomenon of gravitational attraction. A part of the inertial mass of some material objects may be due to their content of concentrated energy; but has it yet been fully established that matter is nothing but a concentration or manifestation of energy?

In a reaction such as the fission of a uranium nucleus a part of the large quantity of binding energy inherent in the first arrangement of the constituent material particles is released, and appears as free energy of motion of the fission fragments. That small proportion of the mass of the original uranium atom, which was the physical manifestation of the binding energy thus freed, disappears as such; or, in common parlance, "is converted into energy."

However, is it not solely a function of rearrangement? Is not the total number of constituent material particles, protons, neutrons, electrons, etc., extant unchanged during the process? Is there any evidence of the conversion of actual matter as such, a material particle itself, into available energy? In fact, is there yet any clue to the circumstances in which such a conversion might occur, or how it might possibly be achieved?

Yours faithfully,
R. A. Laurence, Lt.-Col. R.E.

40, Hedley Street,
Maidstone,
October 24, 1947.

## INTELLECTUAL FREEDOM.

To the Editor of Engineering.

Sir,—In your issue of September 26, on page 302, *ante*, you had a leading article which referred to my address at the Annual Conference of Aslib, which you reprinted fairly fully in the same and following issue. I am writing to point out that, in two respects, the description of the position which you give in the leading article gives a rather different impression from what I tried to explain in my address and that this may give rise to misunderstandings.

You say that "Under the Atomic Energy Act, it is illegal for a physicist working in the field of atomic energy to publish his results . . ." In referring to this situation in my address, I made a special point of explaining that this section of the Atomic Energy Act is largely cancelled by an exemption Order made under the Act. While this does not dispose of the objections one may have in principle to such a sweeping prohibition in the Act, it does affect the practical provision so vitally that it is misleading to quote the clause of the Act without also mentioning the exemption Order.

In a later paragraph of your article, you refer to the situation "under which individual workers, say in university laboratories, find themselves . . ." and you go on to describe declassification procedure in such terms that the reader may easily form the impression that physicists have to submit the results of their work for clearance before publication. I was trying to explain that this arises in the case of university scientists only if they have previously

received confidential information from Government sources and if their work is on a closely related topic. If they are satisfied that, in their research they have not really made use of this confidential information, they are entitled to publish their findings, and anybody who wanted to accuse them of a breach of security would have to prove that such a breach had taken place. The need for clearance, therefore, exists in only a much more limited category of cases than you implied.

In your last paragraph, you speak of the delays caused in the free interchange of scientific opinions over a large branch of physics. I have tried to show that, as the regulations work at present, these obstacles are likely to be serious only in the very special type of research that deals with the fission of heavy elements and the production of atomic energy.

Yours faithfully,
R. E. PEIERLS.

Department of Mathematical Physics,
The University,
Edgbaston, Birmingham, 15.
October 25, 1947.

## THE INSTITUTION OF NAVAL ARCHITECTS.

(*Concluded from page* 377.)

WE conclude below our report of the autumn meeting of the Institution of Naval Architects, held at Portsmouth on September 23 and 24, and at Southampton on September 25 and 26. The preceding instalment of our report dealt with the paper by Mr. W. C. S. Wigley, M.A., and Professor J. L. Lunde, presented at Portsmouth; and with the paper by Mr. O. H. Lewis on "The Port of Southampton," which was the first to be delivered at the technical session on the morning of September 25. It was followed, in the same session, by a paper on "Permanent Moorings," by Mr. T. Thorpe, R.C.N.C., and Mr. K. P. Farrell, B.Sc., R.C.N.C.

### PERMANENT MOORINGS.

The paper gave some of the results of an investigation initiated during the war, the need for which had been strengthened by the call for many new moorings to accommodate ships of the large post-war Reserve Fleet. The aim was to devise a form of mooring which would require less chain than the types in use, while providing increased security against dragging. The scope for improvement was indicated by the success of the "anti-snatch" mooring developed by the Air Ministry for large flying-boats. Model tests were undertaken at Haslar, where the members of the Institution were able to inspect the apparatus and a range of model mooring anchors, on the occasion of the visit to the Admiralty Experiment Works; and, with the co-operation of the Air Ministry, full-size tests were made on the Ministry's mooring test ground at Pwllheli, where the test anchors were hauled over various types of ground by a tractor, using two five-part purchases. The holding power of chain cable was also tested at Pwllheli. Admiralty-pattern moorings, the authors explained, were classified according to a system introduced in 1927 and ranged from first-class, which were suitable for battleships and large aircraft-carriers, to sixth-class, intended for the smallest types of naval vessel; this scale of sizes was based on the diameter of chain cable carried by the respective types of ship and superseded an older method based on the displacement of the ship. The investigation described in the paper covered the forces acting on a moored ship, in addition to the holding power of the anchor and the mooring chain, and resulted in the development of new designs of moorings which achieved a saving of 25 per cent. in the weight of cable required. The improvement was effected by combining a taut pendant with a resilient system of ground chains, with a more efficient form of mooring anchor.

The discussion was opened by Mr. W. A. D. Forbes, who explained how the experiments had arisen, from cases of the dragging of anchors during the war. Lord Fraser, then Commander-in-Chief of the Home Fleet, had suggested that the subject of anchors should be investigated, with a view to increasing their holding power, but it was not until the end of the war that personnel could be spared for the work, which was of considerable magnitude. Meanwhile, a survey of the literature on the subject showed that the knowledge of the characteristics of anchors and their behaviour was very deficient; accordingly, plans were made to find out how anchors really acted and what were the important factors influencing their design. A real start was made when they had ascertained from the Air Ministry information concerning the anti-snatch mooring, which was much more successful for flying boats than the standard type of Admiralty mooring. Mr. Forbes asked whether the new designs of mooring anchors, to which the authors referred, would have the good points of the existing mooring anchor and would not bury themselves completely in the mud; they did not want an anchor which might be lost.

Lieut.-Commander D. H. MacMillan, R.N.R. (ret.), said that there should be much more collaboration between those who studied the theory of moorings and the practical users of them. Without such co-operation, the seamen would take an empirical view, and other gentlemen would put forward very strange views without having any practical experience. As a hydrographic surveyor, he felt there was room for such collaboration also in determining the merits of holding ground; that matter in the past had been determined largely on the experience of seamen. There had been superficial determinations, but he felt that surface borings should be made, in order to determine what good holding ground really was. During the past 50 or 60 years, the machinery on board ship had been so developed that almost any anchor could be weighed. He thought, however, that development of anchors had not kept pace with the ability of ships to handle anchors. All such matters called for collaboration between naval architects, scientists and seamen, and he hoped that the paper would receive proper publicity among the "tarry Jacks" who, though they might not know the calculus, could put two and two together.

Mr. S. T. Cope observed that the paper gave details of some new mooring designs which achieved, a 25 per cent. saving of cable, and considered that from that point of view alone, the work had been well worth while. During the war, he understood, the total capacity of the chain-cable industry in this country was sufficient to produce only 60 per cent. of the cable and associated equipment required to meet the needs of the three Services, so that someone had had to go short. The Admiralty were the greatest consumers of that material. The Air Force had had to improvise and to use worn and second-hand chains. Dealing with the reference in the paper to the overhaul of Admiralty moorings at home Dockyards in accordance with the general rules laid down, he suggested that it was almost impossible to lay down a schedule of maintenance without incurring wastage of man-power and ships. For example, one of the general rules was that first-class and second-class moorings were examined annually by divers. The Royal Air Force had given up that practice about ten years ago, as being a waste of time. Another rule mentioned in the paper was that first-class and second-class moorings were raised entirely every five years for thorough survey and repairs. The Admiralty and Trinity House had a large number of moorings in the Medway. Chains and buoys in the Medway had a useful life of 10 to 15 years, but in the vicinity ofthe outer bar they would last for about 18 months. A standard of maintenance for moorings, presumably, would be based on the minimum requirements to safeguard those moorings, so that those in the Medway would be examined and overhauled every 18 months. Trinity House and the Admiralty probably had records covering 50 or 100 years; a study of the records might show that, although they had examined the moorings at shorter intervals, in many cases they had not renewed anything for 10 years. Surely, therefore, maintenance schedules should be amended in the interests of economy in man-power and ships.

The President (Lord Chatfield) said that he was impressed by a table in the paper showing the effect of forces due to a 60-m.p.h. gale or to a 5-knot tide; the figures might give the impression that, whereas wind was very important, the tide was much less important. That was so, he said, provided that one had a ship in a fore-and-aft line with the wind and the tide. Directly there was a combination of wind and tide, far greater forces were brought into play than could be produced by the maximum effort of either alone. If, for instance, a ship were riding through a 60-m.p.h. gale, the wind was simply acting on the thwartships section and its effect was limited. If the ship were riding to a 5-knot tide with a gale on her quarter or her beam, which swung her round so that she was at an angle of, say, 20 deg. to the tide, the tide would push her against the wind and she would drag her anchors or part the cables. That experience was familiar to those who, during the first world war, were anchored at Rosyth, where there was always, at springs, a tide of about 4 knots. When there was a gale, every ship swung around about 20 deg., and sometimes 30 deg., with the tide. The biggest ships would drift to windward and go ashore, whereas the small ships were not affected. In 1919, at Liverpool, he had had the same experience, when the battle-cruisers Tiger and Princess Royal used only their anchors, and he had taken the battleship Queen Elizabeth to the Cunard buoy. One night, both the Tiger and the Princess Royal parted their cables, for the tide was running at about 10 knots; they asked permission to proceed to sea and both went to Scapa Flow with neither anchors nor cables. The Queen Elizabeth held to the Cunard buoy for three days at high tide and did not part her cables, although he had thought they would go at any moment.

Mr. Thorpe, replying to Mr. Forbes's question whether the new anchor that was being developed would become lost in a soft bottom, said that they were trying to ensure that it would not become lost entirely in the mud. Replying to Lieut.-Commander MacMillan, he said they were securing collaboration, and had done so in the past, partly by contacts with Mr. Cope and his colleagues, and by conducting trials at various places, with the co-operation of the local Moorings Officers. The reference to the holding power of the various grounds coupled up with Mr. Cope's remark on the 25 per cent. saving of cables, and Mr. Thorpe admitted that the figure of 25 per cent. was an over-estimate. They could not always cater for firm sand, so that they could not always effect a saving of 25 per cent. The authors had not lost sight of the fact that ships were better equipped nowadays for weighing anchor than was formerly the case. They hoped to contribute another paper dealing with the anchor dragging trials, and that matter had been taken into account. As to maintenance schedules, mentioned by Mr. Cope, it was left to the local Moorings Officers to cater for that in accordance with local conditions. Finally, in a comment on the President's remarks, he said that, though it was said that mathematics could prove anything, it was necessary to go to the practical man to ensure that such a point as the President had mentioned, when a ship slewed round by the forces imposed, was not overlooked.

Following the morning session, the members and their guests adjourned to the Polygon Hotel, Southampton, where they were entertained to luncheon by the Mayor of Southampton (Alderman F. S. Smith, J.P.); and, in the afternoon, at the final technical session, a paper was presented by Mr. J. F. Allan, B.Sc. and Mr. W. P. Walker, on "The Resistance of Barges in Deep and Shallow Water."

### THE RESISTANCE OF BARGES.

The paper described two groups of resistance tests of barges of various forms in common use, carried out in the experiment tank of Messrs. William Denny and Brothers, Limited, Dumbarton. The types tested were of limited draught, designed for use on rivers where, for part of the year, the depth of water was restricted; and it was pointed out that the degree of accuracy obtainable in such shallow-water tests was not to be compared with that of normal deep-water testing. Deep-water tests, in Group I of the series, were made with four forms, namely, the ship-shape, the spoon-shape, the swim-ended barge, and the scow type. Two models, 12 ft. long, were made of each type, and were tested singly and in pairs, combined in various spacings, abreast and

in line. It was found that, for single barges, the spoon shape gave the lowest E.H.P. over the speed range taken, and that the scow shape was the worst at all speeds. Fleeting two barges abreast caused an increase in resistance except with scow-shaped barges hard against each other, which showed a small gain. Fleeting in tandem reduced the resistance. The shallow-water tests in Group I applied to two shapes only, the ship-shape and the swim-ended, and showed that the interference due to fleeting abreast was accentuated in shallow water; while the small gain in tandem fleeting became a small loss, in the case of the ship shape. In Group II of the tests, spoon-shaped and scow-shaped models were tested; they were 7·7 ft. long, with fuller forms than in Group I, and the scow models had "hard" bilges. The results showed that, for single barges and for combinations of two, the scow shape was always more severely penalised by restricted depth than the spoon shape. In general, it was found that the shallow-water tests were difficult to compare; but they appeared to indicate that, the more the flow of water was pushed under a barge, the earlier and more severe was the effect of limited depth.

Dr. G. S. Baker, who opened the discussion, suggested that the authors might make shallow-water tests over the mud bank off Helensburg; if they could persuade some of the shipowners to run ships there, the Teddington authorities would lend them a dynamometer, and he was sure that some first-class results would be obtained. He asked whether the models used by the authors were restricted from yawing when they were towed, because, if a model were allowed to yaw when towed in shallow water, one obtained an early indication of eddy making, particularly at the fore end.

Professor A. M. Robb recalled that, about 1905, R. E. Froude had suggested that the phenomena of shallow-water resistance were merely the phenomena of deep-water resistance with every factor accentuated. The constriction of the flow involved, first, an increased water velocity, and therefore, increased frictional resistance. Mr. Allan, in presenting the paper, had said that although he had taken the speeds up to that at which increased wave-making became prominent, it must not always be assumed that all the resistance was frictional One of the curves, however, indicated that the shallow-water resistance was 5·1 times the deep-water resistance, which meant that there was no excess wave-making resistance; but the frictional resistance was practically five-fold in shallow water as compared with deep water. That seemed a little questionable. What Froude's contention amounted to was that, since the shallow-water effects were the deep-water effects accentuated, there were larger waves because of the increased pressure changes, and also longer waves for a given speed; therefore, the wave interference effects should be more pronounced in shallow than in deep water. He had searched all the reliable records of shallow-water trials, however, and could find no trace of that. He had now grave doubts, Professor Robb added, whether the assumption which had been accepted for 70 years, that frictional resistance could be separated from wave-making resistance, was valid. Perhaps shallow-water tests might point the way to a different line of approach.

Mr. L. Woollard, referring to a diagram in the paper showing the barges being towed in tandem, practically touching, asked if they were towed bow to stern and actually in contact; to which Mr. Allan replied that the bow and the stern were touching, though, of course, there was a clearance on the water line.

Mr. Walker, replying briefly to the discussion, said, in answer to Dr. Baker's question, that all the barges were permitted to yaw when towed.

This concluded the business of the technical sessions, the rest of Thursday, September 25, being devoted to visits to the site of the former shipyard at Buckler's Hard, near Beaulieu, where many wooden warships were built, and to Winchester. On the following day, the members visited the Woolston Shipyard of Messrs. J. I. Thornycroft and Company, Limited, and subsequently embarked in the M.V. Vecta for a cruise down Southampton Water and in the Solent.

# SYMPOSIUM ON INTERNAL STRESSES.

(*Continued from page* 402.)

The second session of the "Symposium on Internal Stresses in Metals and Alloys," organised by the Institute of Metals in association with six other technical societies, was held on the afternoon of Wednesday, October 15, under the chairmanship of Professor Leslie Aitchison. It dealt with the 16 papers contained in Section II.

## Origin, Control and Removal of Internal Stresses.

The *rapporteur* of the section, which related to the "Origin, Control and Removal of Internal Stresses," was Professor H. O'Neill. He stated that one of the papers in the section, by Mr. J. C. W. Humfrey, described the "Stresses Induced by the Shot-Peening of Leaf Springs." In this piece of work an attempt had been made to measure the amount of stress produced by the peening by removing the surface of the treated spring. Mr. Humfrey's procedure was to dissolve away the outer layers of steel in hot dilute sulphuric acid. After removing the metal in this manner, the camber of each spring plate changed, and, by calculation, the internal stress present in the layer which had been dissolved away was arrived at. This led to results of the order of 35 to 60 tons per square inch compressive stress in the surfaces. These agreed fairly well with the results contained in a paper on "Internal Stresses in Railway Materials" to be given on the morrow, in which X-ray measurement had shown the surface stress of shot-blasted springs to be between 50 and 60 tons per square inch. A point for discussion was whether this solution method, using hot sulphuric acid, with no mention of an inhibitor, might induce stresses of its own. In fact, in another paper in the present section Dr. H. Elliss, spoke of the danger of pickling castings because hydrogen might be introduced and produce an internal stress due to gas pressure.

A paper by Mr. A. W. Hothersall was concerned with the measurement and the origin of stresses in electrodeposits, and he mentioned that chromium deposits might contain a tensile stress of up to 30 tons per square inch. A "Classification and Nomenclature of Internal Stresses" was the title of a paper by Dr. E. Orowan, F.R.S., and in this the author stated that internal stresses existed in bodies upon which no external forces were acting; hence this was really what the meeting was dealing with. A paper by Mr. W. C. Hynd on "Internal Stresses in Glassware" had been invited by the Symposium Committee to act as a kind of "blank" to the discussion on crystalline metals. Eight papers, in which the actual occurrence of stresses was considered, had been submitted. One by Dr. F. P. Bowden and Mr. A. J. W. Moore, entitled "Internal Stresses Produced by the Sliding of Metals," dealt with stresses on a very small scale.

At the other end of the range Messrs. M. C. Caplan, L. B. W. Jolley and J. Reeman described body effects in their paper "Some Internal Stresses in Turbine Rotors." In the first part of their paper these authors had studied stability of dimensions when the rotor was in the fully-annealed condition, and then, for comparison, when the steel had been normalised and tempered. It should be emphasised that the normalising and tempering was not followed by any quenching; the tempered rotor had been furnace cooled. The results showed that the annealed rotors and the normalised and tempered rotors had given rise to no important changes of dimensions, so that, apparently, there was no great difference in the amount of residual stress.

Large-scale work and large stresses were dealt with in three papers, one by Mr. G. Forrest on "Residual Stresses in Beams after Bending"; one by Dr. H. Elliss on "Internal Stresses in Steel Castings"; and one by Mr. R. Weck on "Residual Stresses Due to Welding." Mr. Forrest's paper was largely theoretical and dealt with the plastic bending of beams and the stresses which remained in beams of different section when stressed beyond the elastic limit. It was pointed out that in such cases the stresses might approach the ultimate tensile stress of the material. In some metal-bending and shaping operations, an important technical consideration was the "spring-back" after the stressing had been accomplished and this aspect had been considered by Mr. Forrest. Dr. Elliss's paper on castings was very useful. He studied hot-tearing in relation to the composition and the methods of manufacture of a steel and it appeared that, with the higher carbon steels, there was much greater liability of stress cracking. This was a point which arose in connection with such components as railway tyres, which, as a result of braking effects during operation, could become quite hot, and stress cracks occurred on the treads. It was a rough-and-ready observation that the lower-carbon tyres were less liable to this cracking than the higher-carbon tyres.

Mr. Weck was concerned with welded structures, and made the important statement that internal stresses must arise from plastic deformation, and that, if steel were involved, these plastic deformations, in turn, might produce strain-ageing troubles. Mr. Weck made some welding tests on a specimen held in a large stiff frame, and he found in his procedure that the internal stresses could exceed the yield point of the material. Finally, he raised the important point of the effect of internal stress on the fatigue limit. Mr. D. G. Sopwith, in his paper, "The Production of Favourable Internal Stresses in Helical Compression Springs by Pre-stressing," gave an account of the increased endurance value of helical steel springs as a result of previous plastic deformation by the operation known as "scragging." Springs had been scragged for many years, partly as a testing procedure and partly to improve them, and Mr. Sopwith was able to show that these particular helical springs were improved as a result of a scragging treatment before putting them in service. Mr. A. G. Warren, in a paper dealing with "Autofrettage," also outlined the effect of pre-stressing upon large structures, such as pressure vessels or gun tubes. The name of Major (now Major-General) A. E. Macrae, O.B.E., was associated with this process, and the author showed that, in the light of the information available to Macrae when he carried out his work on over-strain in metals in 1930, he had obtained reasonably good results. Since then, however, the maximum shear-stress theory of failure had been considered inadequate, and this would now explain discrepancies between Macrae's results and actual practice.

Two papers in the section dealt with the removal of internal stresses. The first, by Dr. W. Betteridge, discussed the removal of internal stresses in light alloys after quenching from the solution heat-treatment temperature. As the author pointed out, these alloys could be quenched in either cold or boiling water, the latter method reducing the amount of internal stress in the finished product, but with a loss of some of the mechanical properties. One method of dealing with these residual stresses was to cold work the component. The other paper on the removal of stresses was by Sub-Committee T.S. 17 of the Technical Council of the Institute of British Foundrymen. This dealt with the treatment of iron castings. Engineers were anxious that these castings should be stable if machine parts, such as lathe beds, were to be made from them, and the castings were often left out in the open for quite long periods of time in the hope of obtaining stability. The sub-committee recommended that treatment at 450 deg. C. would reduce the chance of cracking and distortion in iron castings, and that all internal stresses were relieved by treatment at 600 deg. C. Finally, Dr. M. Cook's paper on "The Relation of Composition to Stress-Corrosion Cracking in Copper Alloys" was an excellent summary of existing information regarding the liability of copper alloys to fail by cracking, generally intercrystalline cracking, when corrosive influences were at work. Season cracking had received quite a lot of attention, but stress corrosion (in which the stress was externally applied) was causing much trouble at the present time. Dr. Cook showed that metallic copper seemed to be free from stress-corrosion effects and brasses containing not more than 15 per cent. of zinc were reasonably immune from season cracking. Silicon additions of up to 1·5 per cent. were beneficial to 70 : 30 brass.

(*To be continued.*)

# THE FUEL ECONOMY CONFERENCE.

(*Concluded from page* 378.)

We conclude below our report of the Fuel Economy Conference, which was held at The Hague from September 2 to 9, by summarising the general reports of Mr. M. L. Kalff on Section B2 (Distribution of Liquid and Gaseous Fuels); Mr. B. A. M. van Dorp on Section B3 (Energy in the Form of Heat); and Professor A. J. ter Linden on Section C5 (Space Heating). The first-mentioned of these sessions was held in the afternoon of September 8, and the others on September 9, followed in the afternoon of that day by the official closing session.

### Distribution of Liquid and Gaseous Fuels.

Five papers were presented in Section B2, one dealing with the transport of petroleum fuels, especially in France, and the others with the manufacture and distribution of gas; but Mr. Kalff, in his report, did not comment extensively on any of them, except in the case of the paper by Mr. A. Evain, which discussed the linking of steelworks by gas mains as a means of balancing the load in power stations. On this paper, Mr. Kalff commented that, as it was concerned with gases of a calorific value at the lower end of the scale, the conclusions drawn were not readily applicable to other conditions. He suggested as a matter for discussion, however, arising from the papers, whether, in France and possibly in other European countries, it would be feasible to employ what he termed "multiple-product" pipelines, through which might be pumped, at different times, fuels ranging from fuel oil or even light residual fuels to petrol, thus making pumped distribution economic in circumstances where it might not be so if confined to a single type of fuel. Two of the papers, one being a Belgian contribution and the other from Czechoslovakia, discussed the factors influencing the economic aspects of long-distance gas transmission, and these gave rise to further suggested topics for exploration; namely, whether the figures given by Mr. van den Hende (chief engineer of the Société Distrigaz, Brussels) were in agreement or not with those given by Mr. Evain, and might be compared over a wider range, and what values might be regarded as reasonable for the loss of gas by leakage from pipelines. In the paper by Dr. Rudolf Riedl, of Czechoslovakia, a leakage loss of 6 per cent. was mentioned in the case of certain relatively old pipe systems, but without reference to the length of the pipeline, its method of construction, or the pressure maintained in it. He suggested, too, that information on the methods of maintenance and cost of maintenance of pipelines might be collected with advantage from the delegates.

### Energy in the Form of Heat.

The fact that only one paper was submitted in Section B3 made it a little difficult, Ir. B. A. M. van Dorp observed, to submit a general report; but, in fact, on the basis of Mr. P. Houbin's paper describing the district-heating installation in Paris, he did contrive a report which suggested a number of directions for inquiry of a general nature. Broadly speaking, he said, European practice in the transport of heat-energy over considerable distances favoured the high-pressure hot-water system, whereas American practice showed a preference for steam, as did the French installation described by Mr. Houbin. Technical opinion in the Netherlands regarded the use of steam for this purpose as being somewhat out of date. Other questions were whether the generation of heat in a special boiler-house was the best method, or whether it was more economical to combine district heating with electric-power generation; whether pipes should be laid in watertight ducts or directly in the ground; and whether, if a district-heating system were provided, there should be an obligation to connect to it all houses within its area, assuming the tariff to be reasonable. Pipe insulation, and the maintenance of watertightness in pipelines laid in the subsoil, presented big problems in the conveyance of heat, Mr. van Dorp continued; he would prefer the pipes to be carried overhead, as was often done in factories, but, where this could not be done, they might be taken through the basements of adjoining houses. He inquired whether, with the steam system, metering was easier than with hot water; whether the length of 18½ miles, quoted by Mr. Houbin, included the secondary and tertiary pipelines of the Paris system; and why the ratio of yearly heat output to maximum hourly output, given as 2,300, was so much higher than the corresponding ratio, 1,400, in the only Dutch district-heating installation, at Utrecht. Various questions on the detail design of the Paris system were put to Mr. Houbin, in amplification of his paper, and, finally, Mr. van Dorp suggested four points for discussion by the Conference. The first was the need to reduce the temperature of the steam supplied, in the case of a wholly-steam installation, to a figure that would be tolerable in buildings; in a hot-water system, this reduction could be accomplished by an admixture of the return water, a method which was cheaper and less complicated than the other. The second point concerned the basis on which the cost of fuel should be calculated, especially in the case of a combined heating and power plant, possibly situated where the cost of fuel and/or insulating material was high; the third topic was the best method of ensuring watertightness of insulated pipelines, in the light of the experience already gained in several countries; and the fourth was the question whether the choice of a working boiler pressure should depend on fuel economy, on the economics of electric-power generation, or on the capital cost of the district piping system.

### Space Heating.

The summary presented by Professor A. J. ter Linden, *rapporteur* for Section C5, covered six papers, the countries represented being Denmark, France the Netherlands, Norway, Sweden and the United States—most of them, it will be noted, accustomed to a fairly wide range of temperature, but not all well endowed with natural fuel resources. In many countries, Professor ter Linden remarked, space heating required a considerable portion of the total fuel consumption; in Holland, the figure was about 35 per cent. Mr. A. Nessi, who contributed the French paper, considered that about 50 per cent. of the space-heating consumption in France might be saved, and Professor ter Linden thought that this ratio was probably applicable to most other countries. The first essential, however, was to determine the necessary standard of comfort. The instruments commonly used did not register all the factors which influenced what he called "indoor heat comfort," and practice in measurement varied in different countries; he suggested the desirability of evolving an international standard method of assessment. Several of the papers reviewed discussed the economics of district heating and expressed somewhat different views. Mr. E. C. Jonsson and Mr. E. Lagerstedt, of Sweden, thought that a district heating plant which displaced a large number of small heating boilers would save "a considerable amount" of fuel, especially if a combination of heating and power production were possible. Mr. W. F. Davidson and Mr. M. J. Steinberg (United States) said that the district-heating system in New York, using exhaust steam, effected large savings in 1946, and larger savings were expected in 1950, when the modernisation of the Waterside power station would be completed; but, they added, the capital outlay was considerable, and in many cases the financial advantage of district heating became doubtful. Ir. M. C. Hoenkamp (Holland) supported this by stating that the planning of a district-heating system for Rotterdam showed that, if heating and power production were combined, the capital cost per heat unit became excessively high. A more economical solution, in this case, was to combine only the base heating load with electricity production, and to use a few small supplementary boiler plants, in the centre of the town, to meet the peak load. Circumstances favoured district heating if the heat consumption per unit of site area was high, as in New York and other large cities; if part of a city had to be rebuilt, as in Rotterdam; or if fuel prices were relatively high, as in Denmark, where practically all fuel had to be imported. Mr. A. K. Bak and Mr. N. C. Geertsen (Denmark) went farther, however, and expressed the view that district heating was also justified for comparatively small towns, in combination with electric-power generation. Professor ter Linden suggested that the Conference might inquire into the possible fuel saving to be expected from the use of a good automatic control of heating systems; the effect of different proportions of radiant heat and convection heat on the heat input needed to give the same level of warmth for normal domestic heating; and the technical and economic problems of district heating in combination with power production.

### Closing Session.

The closing session, on the afternoon of September 9, was presided over by Mr. Ernest Mercier, vice-president of the International Executive Council of the World Power Conference, who opened the proceedings by reading a message from Sir Harold Hartley, the chairman of the International Executive Council, who had been prevented by illness from taking part in the conference. He reminded the members of the ideals which the founder of the World Power Conference, Danial Nicol Dunlop, had had in mind—"the advantages that would accrue, both socially and technically, by bringing together at intervals those who were interested in the great field of energy, the sharing of experience, and the making of friendships on an international scale." The World Power Conference, continued Sir Harold, could play a great part in reconstructing the civilisation of a world made poorer by the wastage of war, by helping to re-establish a community of interest between nations. Of all the material factors in this reconstruction, energy was the most important. He thanked the Netherlands National Committee for the opportunity to meet at The Hague and for the skill and effort they had devoted to the preparations for the meeting; and especially he acknowledged the work of Mr. G. J. T. Bakker for his courageous defence, at great personal risk, of the international status and independence of the Conference while he was acting as chairman of the International Executive Council during the war. The Netherlands had set a great example by the determined and effective way in which they had tackled their many and difficult problems of reconstruction. "In that work," wrote Sir Harold in conclusion, "Mr. Bakker, as Director of Energy Supply, must have played a great part. It was, therefore, a great opportunity for us to hold the Conference under his chairmanship and to discuss this major world problem of fuel economy in a country whose example we all admire."

The remainder of the business was formal, consisting of resolutions of thanks to the Netherlands National Committee, the Technical Committee, the Netherlands Government and His Excellency Dr. G. W. M. Huysmans, Minister for Economic Affairs, the Municipality of The Hague, the Administration of the State Coal Mines, the Netherlands Ladies' Committee, and the various National Committees of the World Power Conference for their several contributions to the success of the proceedings. Though formal, however, in their presentation, the resolutions were supported and carried with a warmth not always accorded to formal motions, for the members and delegates had been highly appreciative, throughout the meetings and social interludes, of the exceptional and most successful efforts of all concerned to overcome the disabilities which inevitably resulted from the years of German occupation.

Mr. C. H. Gray, secretary to the International Executive Committee of the World Power Conference, announced that the Third Congress on Large Dams would be held in Sweden in 1948, and the official proceedings then terminated. In the evening, however, the social objects envisaged by the late Mr. Dunlop, as quoted above from Sir Harold Hartley's address, were further advanced by an informal gathering in the Kurhaus at Scheveningen; and on the following day parties of the members visited the refineries of the Royal Dutch-Shell Petroleum Company at Pernis, the laboratories of the same company at Amsterdam and Delft, the high-voltage and hydraulic laboratories at the Technical School at Delft, and the electrical works of Messrs. Philips at Eindhoven.

## THE WORK OF SHIP CLASSIFICATION SOCIETIES.*

By J. L. Adam, C.B.E., M.I.N.A.

There is probably more welding done in ship work than in any other single industry, and, as the majority of the members of this Institute have little contact with shipbuilding, I propose to give some idea of how the ship classification societies are related to the shipping community, and, incidentally, to welding in ship work. Classification societies definitely demonstrate "government of the people, by the people, for the people"; in other words, the government of the shipping community and all its interests, by the shipping community, for the community to which ships are vital. They are unique in their constitutions and are not paralleled in any other industry. Control is in the hands of a management committee and it is a requirement of the Government that none of the members of the committee may make any profit out of his association with the society. This body represents shipowners, shipbuilders, engineers, steel manufacturers, underwriters and other interests affecting the welfare of ships. It is advised on technical matters by a technical committee, which is even wider in scope.

Each classification society issues "Rules" which quite clearly define the conditions under which the society's standards must be applied and indicate principles for their adaptation to varying conditions. One very important point is that, in all countries, the rules and regulations of any one classification society are the same. That is essential, since shipping is international and not national, far less parochial. After a shipowner specifies the class of the ship to be built, the shipbuilder prepares his structural plans for submission to the particular classification society. There are six of these in active existence to-day and there never were more than eight. These plans are dealt with by a staff which is not only technically qualified, but has practical experience of shipbuilding and of the effects of service on ships, so that, when the plans are returned to the shipbuilder, he will not be asked to do anything that is not a practical possibility. When he receives the plans as approved, the shipbuilder orders his material, and that material is also inspected and tested by the classification society's officers. This applies to every piece of structural material in the ship, its machinery and vital parts of the outfit, and, of course, to the approval and inspection of electrodes when, as is usual to-day, welding is used to a lesser or greater extent in the structure.

The rules also lay down certain requirements for electric welding, including the amount of welding required in the individual parts and the conditions under which it must be applied. When the material is delivered at the shipyard, it comes under the supervision of the society's surveyors at that yard, who check whether the material has been duly inspected and passed by their colleagues at the manufacturers' works. The surveyors must not only have technical knowledge, but practical knowledge of shipbuilding, shipbuilding methods and the limits of tolerance permissible.

In the shipyard, the surveyor has to be assured that the system of supervision and the practices of the yards are such as will maintain consistency in results in conformation with the welding schedules. In a well-organised yard with controlled procedure, there is no great difficulty, but without this, the surveyor's life may be very difficult. It says much for the shipbuilders and for the surveyors that the troubles in service through bad welding are very few and far between. When, however, trouble does occur, the consequences may be serious. When the ship is completed, the surveyor reports to the committee and his report must show that the committee are justified in issuing a classification certificate to the effect that the materials and workmanship are satisfactory and that the ship is in a seaworthy condition.

Ship classification societies have a great advantage over other inspection authorities, in that they have representatives all over the world, who report on the behaviour of the ships in their particular services. These reports are continually analysed and the information obtained is used for the improvement of structures and machinery, whether in the actual scantlings or in riveting, welding, etc. In other words, classification societies are very large research bodies, and, while they are associated with laboratory and experimental work, they have the advantage of being able to use full scale specimens—that is, complete ships—in almost unlimited number. In this connection, any Government department, however efficient, must be at a disadvantage compared with a classification society. I do not think any Government of a maritime nation would wish to dispense with classification societies, as they are assets whose function no single Government department could replace.

*(To be continued.)*

* Presidential address to the Institute of Welding, delivered in London on October 29, 1947. Abridged.

## LABOUR NOTES.

In the course of "Some Observations" printed in the *Monthly Trade Report* of the United Patternmakers' Association, Mr. Ellis Smith, M.P., the general president of the organisation, reviews the progress made by the union since the celebration of its jubilee in 1922. During 1947, he writes, greater headway has been achieved by members than in any previous year. "The financial position is," he says, "creditable to all, our membership is greater than ever, and new members are playing their part in the workshops, trades councils, Co-operative movement, Town Councils, and many other ways. Members are entitled to take some pride in their collective achievements, for we would never have made the advance, had it not been well-known that we were well-organised and determined. The national average time rate which is 6*l*.; hours reduced from 47 to 44 and generally worked into a five-day week; the introduction of payment for holidays; the 44 hours five-day week; and a guaranteed week of not less than 34 hours, mark an advance which calls for congratulation."

"Next year," he continues, "we must turn our attention to shop conditions. We will play our part in production, but it is time that all pattern shops were in keeping with the skill and accuracy that are required from our members. It is of paramount importance that we should all assist in creating a health consciousness which demands the best possible conditions in the pattern shops where our members spend so much time. When I look back, I realise that I worked far too long among dust that should have been carried out of the shop. Many works now have a doctor and nursing service, an ambulance station and equipment. Welfare and health have rightly been given more attention in industry, but we have not made the advance we should in pattern-shop conditions. We must all get busy next year in a great drive for conditions worthy of our craft."

Writing in the same issue of the *Report*, Mr. Beard, the general secretary, deals with inquiries he has received from members regarding the conditions of employment in the Dominions and elsewhere overseas. "There is no doubt," he says, "that there are opportunities for craftsmen, particularly those connected with the building trades, but the prospects are not too good if particular employment is desired. Recently, the London Press published a photograph of a party of disappointed emigrants to New Zealand who were obviously glad to get back to this country. What were the reasons for this return I do not know, but it is clear that the housing situation, for instance, is bad the world over and those intending to take up a new life overseas will have to be prepared to tackle any kind of job, be prepared to work much harder than here, and put up with indifferent housing conditions for a considerable time."

A letter which he had received from the secretary of the Patternmakers' Association at Toronto indicated, Mr. Beard said, that in Toronto, Kingston, Hamilton and Peterboro' short-time working was the rule and there was no room for additional patternmakers. The writer of the letter "further stated," Mr. Beard added, "that members who are contemplating a move to Canada should not be misguided by a rosy picture which the Canadian Government may paint of conditions in Canada." "Indeed, if a slump arises, it will," Mr. Beard thinks, "commence in those countries whose economy was the least upset by war conditions. On the face of things it would appear as if Great Britain may be short of many things in the immediate future, but full employment will not be one of them. Members, therefore, contemplating a move overseas, should make sure they have a job to go to and a place to live in, particularly if they have a family."

A rise of one point in the official index figure which measures changes in the average level of retail prices was recorded between August 12 and September 16, when the figure was 101. The new index is based on a figure of 100 at June 17, 1947. The rise in the August-September period was mainly due to increases in the retail prices of coal and of household soap.

Representatives of the National Union of Mineworkers met representatives of the National Coal Board on Wednesday last week and formally presented their claim for increases in wages. The representatives of both sides expressed "profound regret" that their meeting should have taken place at a time when a number of pits in Scotland were affected by an unofficial strike, and they unanimously called upon the strikers to resume work immediately. On the assumption that the stoppage would be brought to an immediate end, the Board agreed to meet the union on November 5.

According to a ruling given by the Ministry of Labour and National Service to Captain Raymond Blackburn, the Labour Member of Parliament for King's Norton, a person who expressed objection to direction to the mines, or to some other industry, will not be directed to a job in which membership of a trade union is a condition of employment, or in which refusal to join a trade union is likely to cause an industrial dispute. If the refusal of a person in respect of whom a direction is enforced gives rise to an industrial dispute, the National Service Officer can withdraw the direction on the application of the employer. The person concerned will then be available for placing in, or, if necessary, direction into, employment in which his objections to joining a trade union is not likely to cause difficulties.

At a meeting in London, the trade-union side of the Joint Industrial Council for the Royal Ordnance Factories submitted for the consideration of Mr. George Strauss, the Minister of Supply, a plea that these establishments should be employed much more extensively than they are in the construction of mining machinery and other urgently needed civilian requirements. About half of the work of the 22 factories is on purely military supplies; about 25 per cent. of their current activity is on civilian goods, and the remainder of their work is in the production of civilian goods for the forces and in "breaking down" ammunition and obsolete military stores for their raw material. Mr. Strauss pointed out that he had been Minister of Supply for only two weeks, and that he could not decide on such a big question of policy at such short notice. He undertook, however, to make known the trade union's views to the Government, and he promised that an announcement of policy regarding Ordnance factories would be made early in the New Year. He gave an assurance that the present staff of about 40,000 in the 22 factories would not be reduced.

During last week, the steps which the Government propose to take with the object of easing the pressure of the national economic crisis were considered at meetings of the National Joint Advisory Council—on which the trade unions and employers' organisations are represented—and the General Council of the Trades Union Congress. An official communication issued at the close of the Advisory Council's meeting, stated that Mr. Isaacs had informed the members that the Government contemplated the introduction of measures to bring into essential work "those men and women who are making no contribution to the national well-being, including employees in football pools, gambling undertakings, amusement arcades, night clubs, and certain classes of street traders, as well as persons not gainfully employed who are capable of work." The Council decided to hold a special meeting on November 18 to consider the proposals, and to ask the Minister of Labour and National Service to provide for consideration the most up-to-date information available.

It was officially stated, after the meeting of the Trades Union Congress General Council, that consideration had been given to "matters arising on reports from representatives who have been in consultation with the Ministers responsible for the carrying out of the Government's economic and financial policy." "In view," it was added, "of the range of the issues involved in questions calling for early decision, it was decided to hold a special meeting." The special meeting took place on Wednesday this week.

In connection with the transference of workers to essential employment under the Control of Engagement Order, the General Council considered the question of a reciprocal recognition of trade union cards held by members of different unions who are directed from their normal employment to another trade. It was felt that it was desirable in the interests of re-directed persons to re-introduce the system of inter-union recognition of cards which operated during the war, but with the provision that recognition should be for the period of direction only and that the position should be reviewed before the end of 1948.

The two sides of the National Joint Advisory Council have agreed to recommend the Government to postpone for a year the putting into operation of the Pre-War Trade Practices Act. The Government intended to bring the measure into operation on December 30, this year. Both employers and trade-union representatives are agreed that this is no time in which to think of restoring the practices, many of which were in effect, restrictive.

The Caledonian Canal.—The Caledonian Canal, which has been closed for repairs, is now open again for through traffic.

# THE RESISTANCE-CAPACITANCE OSCILLATOR.

Fig. 1.

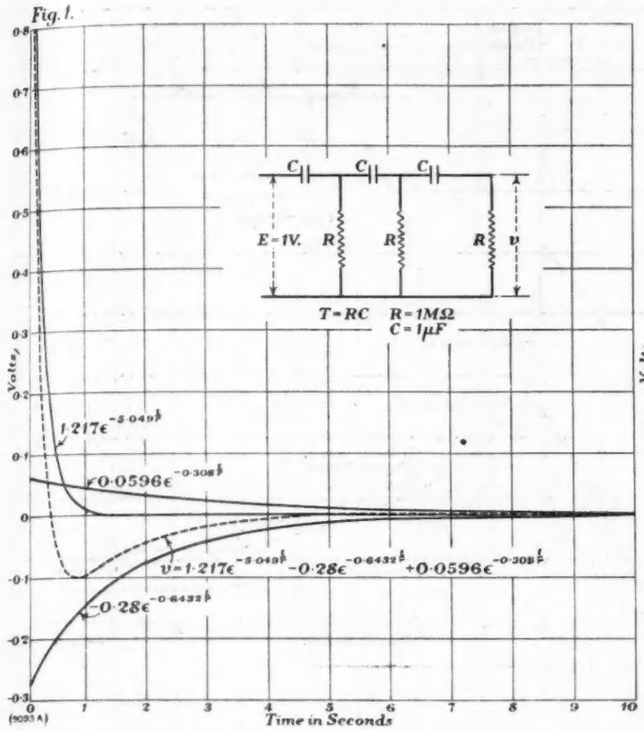
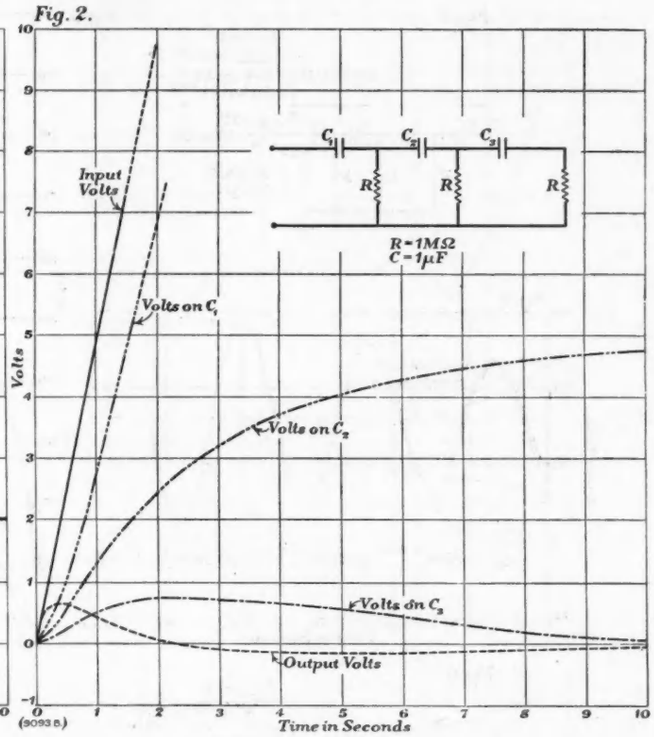



Fig. 2.




## THE RESISTANCE-CAPACITANCE OSCILLATOR.*

By P. G. M. DAWE, B.Sc. (Eng.).

CONVENTIONAL types of oscillatory motion are characterised by energy exchanges between two different forms of storage mechanism. The most common example is the weight and spring mechanism, where the energy may be completely stored at one instant in the spring, as potential energy, and a quarter of a cycle later in the weight, as kinetic energy. With this system the mechanism of oscillation is straightforward, since the oscillation is carried through the equilibrium position by the energy of movement of the weight, and returned from its extremity by the release of the energy stored in the constrained spring. The analagous electrical case is the inductance-capacitance circuit where the energy may be completely stored at one instant in the magnetic field of the inductor, and a quarter of a cycle later in the electrostatic field of the capacitor. Such systems will oscillate freely provided sufficient energy is supplied to overcome the resistance losses.

The phase-shift oscillator, however, is distinguished from these types in that it contains only one type of energy storage. This is generally in the form of capacitance and there are usually two or more capacitors, together with resistors and one or more valves, in the complete circuit. Since the production of a magnetic field does not occur, no energy can be stored by this means and such a circuit has no "energy of motion." Thus the question first arises as to the manner in which the oscillation is carried through the equilibrium position, *i.e.*, although the conditions necessary to maintain an oscillation in such a circuit are readily deduced for the steady state, it is not obvious at first sight how the oscillation is initiated and allowed to build-up. The object of this investigation, therefore, has been to clarify the mechanism of oscillation and to examine the character of the building-up process in the main types of oscillator in common use.

The behaviour of the oscillator has been investigated from a transient viewpoint. This may be done both theoretically, by using the Heaviside step function method of analysis, and experimentally, by injecting a step, or other form of pulse, into the various circuits being analysed. The oscillators investigated are single-valve oscillators, employing a three-mesh RC network having 180 deg. phase shift at the operating frequency, and a two-valve oscillator employing a two-mesh zero phase-shift circuit. In the former type either series capacitors and shunt resistors may be employed, or the inverse, *i.e.*, series resistors and shunt capacitors. These circuits are shown in Figs. 3, 6 and 8, on page 430.

The transient behaviour of the three-mesh series-capacitor type circuit has been investigated by examining both the behaviour of the isolated feed-back network and of the complete circuit in the presence of the valve. It has been found that this is helpful in elucidating the mechanism. A theoretical examination of the feed-back network yields a third-order differential equation for the output voltage, as follows:

$$(p^3 T^3 + 6p^2 T^2 + 5p T + 1)\, v = 0$$

where

$$p = \frac{d}{dt}; \quad T = RC.$$

The roots of the auxiliary equation are found to be:

$$\alpha = \frac{-0{\cdot}3079}{T}; \quad \beta = \frac{-5{\cdot}049}{T}; \quad \gamma = \frac{-0{\cdot}6432}{T}.$$

The transient solution for the output voltage on the application of a step of voltage of magnitude $E_1$ to the input, is given by the Heaviside expansion theorem as:

$$V_0 = E_1 \sum_{x=\alpha,\,\beta,\,\gamma} \frac{x^2 T^2 \epsilon^{xt}}{3x^2 T^2 + 12x T + 5} \cdot 1 \quad \text{(see } \textit{Appendix} \text{ (i))}$$

and substituting the values of $\alpha$, $\beta$, $\gamma$ in this expression gives the final solution for the output voltage as:

$$V_0 = E_1 \left(1{\cdot}217\epsilon^{-5{\cdot}049\frac{t}{T}} - 0{\cdot}280\epsilon^{-0{\cdot}6432\frac{t}{T}} + 0{\cdot}05964\,\epsilon^{-0{\cdot}3079\frac{t}{T}}\right) \quad . \quad . \quad (1)$$

*i.e.*, the exponential indices are all real and negative so that no true oscillation can occur. It is seen, however, that the coefficients of the exponential terms alternate in sign and decrease in magnitude along the series. This means that the transient response to a unit voltage step does involve voltage reversals at the output having the physical character of a heavily-damped oscillation. Physically, this is due to the initial charging and subsequent discharging of all the capacitors, except the one to which the voltage step is applied. The output voltage from the network thus exhibits an "over-swing" effect, the number of over-swings being dependent on the number of meshes present. The graphical solution has been computed for values of R and C equal to one megohm and one microfarad, respectively, and is shown, together with the circuit, in Fig. 1.

It is also useful to consider the transient response of the circuit to a constant rate of rise of input voltage. The result may be obtained theoretically by the use of the Duhamel integral theorem (see *Appendix* (ii)). If the applied wave rises uniformly at E volts per second, starting from zero, the total response of the network is given as:

$$V = E \int_0^t g\,(t-\tau)\, d\tau$$

where $g\,(t)$ is the response to unit step function. Substituting equation (1) for the function $g\,(t)$ and evaluating gives the solution for the output voltage as:

$$V_0 = E\left(-0{\cdot}242\,\epsilon^{-5{\cdot}049\frac{t}{T}} + 0{\cdot}4355\,\epsilon^{-0{\cdot}6432\frac{t}{T}} - 0{\cdot}1935\,\epsilon^{-0{\cdot}3079\frac{t}{T}}\right)$$

The voltages across all three condensers may be evaluated in a like manner. The solution has been computed for a rate of rise of 5 volts per second extended to infinity, and for values of R and C as before. The results are shown in Fig. 2.

It is seen from the graphs that even although the input voltage continues to rise at a uniform rate the output voltage falls to zero, subsequently becoming negative, before finally becoming zero, *i.e.*, the third condenser will ultimately reach a discharged condition whatever rate of rise of input voltage is maintained.

The circuit, together with the valve, as shown in Fig. 3, page 430, may now be considered. The oscillation is initiated by the introduction of a step of voltage of magnitude $E_1'$ in the anode circuit, which is equivalent to a step $E_1$ in the equivalent circuit where $E_1 = E_1' \frac{R_A}{R_L + R_A}$. The differential equation is now modified so that it has one real root, and a pair of complex conjugate roots, provided that the effective $\mu$ of the stage (*i.e.*, the stage gain) is greater than a certain critical value (1·11). The differential equation is

$$\left[\left(1 + \mu + \frac{3R_0}{R}\right)p^3 T^3 + \left(6 + \frac{4R_0}{R}\right)p^2 T^2 + \left(5 + \frac{R_0}{R}\right)p T + 1\right] v = 0 \qquad \left(R_0 = \frac{R_A R_L}{R_A + R_L}\right)$$

and the roots of the auxiliary equation for values of $\mu = 35$ and $\frac{R_0}{R} = 0{\cdot}01$ are:

$$\alpha = -\frac{0{\cdot}1946}{T}; \quad \beta = \frac{1}{T}(+0{\cdot}0136 + j\,0{\cdot}3803); \quad \gamma = \frac{1}{T}(+0{\cdot}0136 - j\,0{\cdot}3803).$$

* Paper read before Section G of the British Association at Dundee on Monday, September 1, 1947. Abridged.

# THE RESISTANCE-CAPACITANCE OSCILLATOR.

Fig. 3.

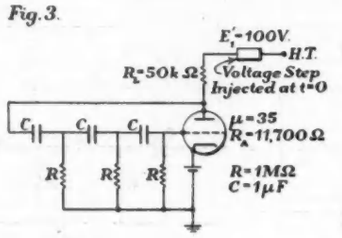



Fig. 4.

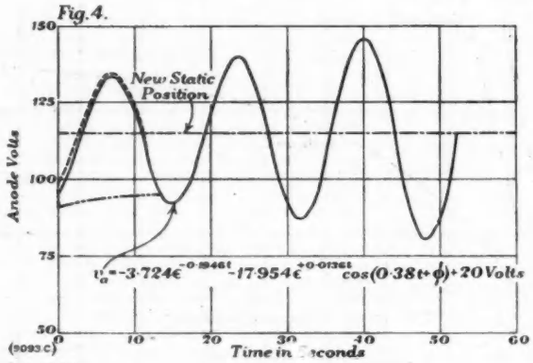



Fig. 5.

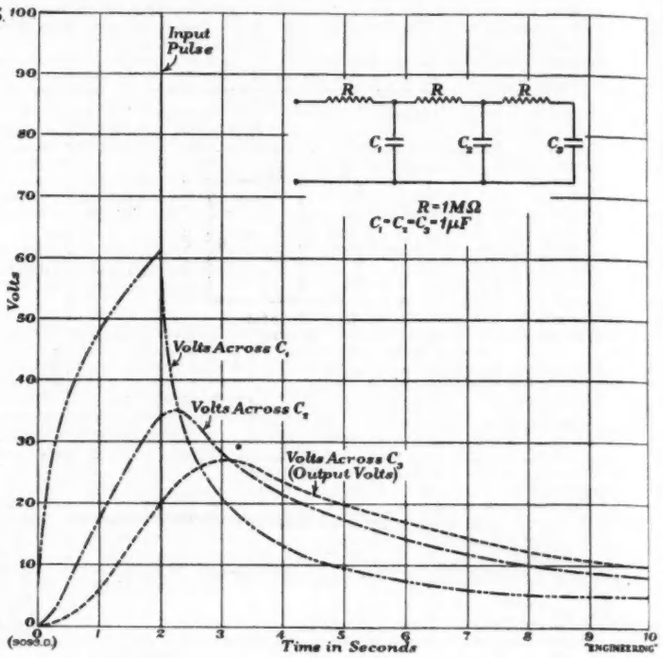



Fig. 6.

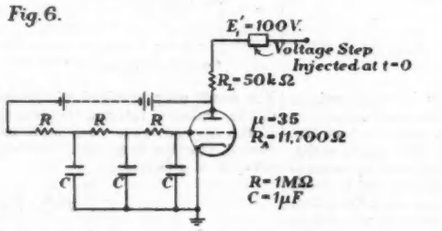



Fig. 7.

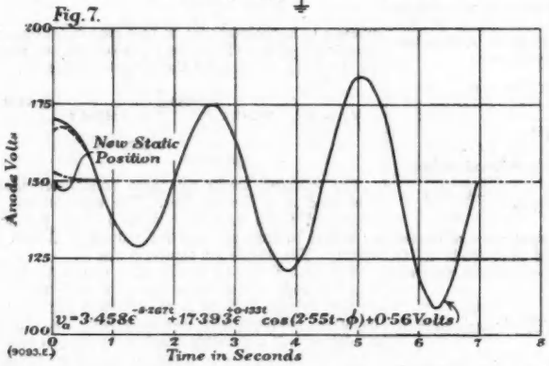



Fig. 10.

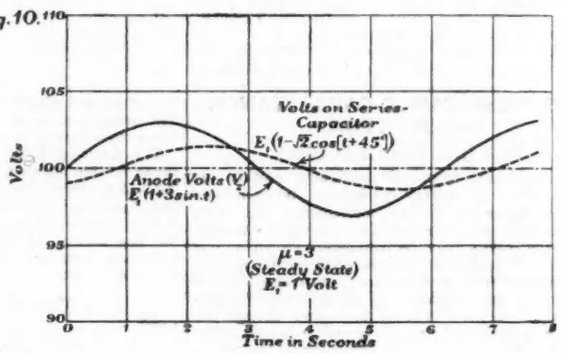
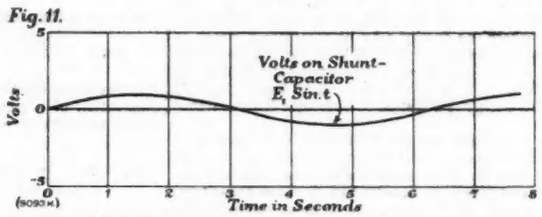



Fig. 11.




The complete expression for the grid voltage is given by the Heaviside expansion theorem as:

$$v = E_1 \sum_{x=\alpha,\beta,\gamma} \frac{x^2 T^2 \epsilon^{xt}}{3\left(1+\mu+\frac{3R_2}{R}\right)x^2T^2+4\left(3+\frac{2R_2}{R}\right)xT+\left(5+\frac{R_2}{R}\right)} 1$$

and substituting the values of $\alpha$, $\beta$, $\gamma$ in this expression gives the final solution of the grid voltage (with $R = 1M$ ; $C = 1\mu F$) as:

$$v_g = E_1\left(0{\cdot}0056\epsilon^{-0{\cdot}1946t} + 0{\cdot}027\epsilon^{0{\cdot}0136t}\cos\left[0{\cdot}38t + 28 \text{ deg.}\right]\right).$$

The solution for the anode voltage has been computed for an effective $\mu$ of 35 and a value of $E_1' = 100$ volts, and is shown graphically in Fig. 4.

Physically, the inception of the oscillation may be described in the following manner. The introduction of a voltage step in the anode circuit to initiate the oscillation, changes the static anode voltage of the valve, raising it slightly. The anode potential cannot, however, rise immediately to this new static position, due to the heavy positive feed-back caused by the capacitors acting momentarily as a short circuit. The potential therefore jumps a very small amount and then rises slowly towards this new value as the capacitors charge, reaching it when the grid capacitor has acquired its maximum charge, the bias on the valve then being the static bias. This, however, is not an equilibrium condition for the grid capacitor, which now proceeds to discharge. The anode voltage is thus carried beyond its new static position, since the discharge of the capacitor causes the grid voltage to become more negative than the static bias. The input to the network has now been subjected to a step of voltage followed by a finite rate of rise of voltage. Fig. 2, however, has shown that the application of a finite rate of rise to the network results in an output voltage which subsequently reaches a maximum negative value, finally returning to zero. Hence the anode voltage must reach a maximum positive value, i.e., a turnover point, and again return to and pass the equilibrium point. Thus the oscillation is initiated.

Fig. 8.

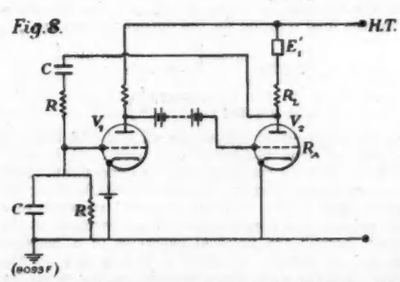
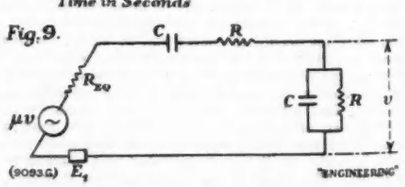



Fig. 9.




The mathematical solution represents a wave of constant frequency increasing exponentially without limit, and thus implies linear valve characteristics of infinite extent. The value of the exponential index in the equation for the oscillation determines the rate of

# THE RESISTANCE-CAPACITANCE OSCILLATOR.

Fig. 12.

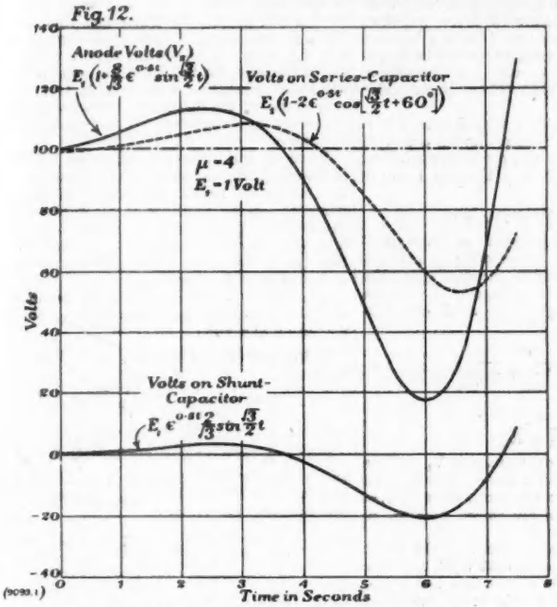



Fig. 13.

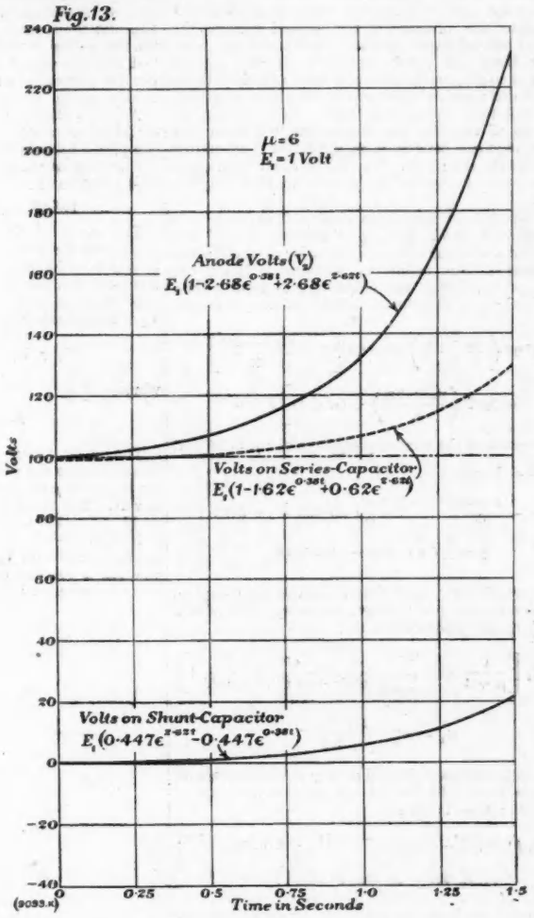



Fig. 14. FREQUENCY VARIATION WITH INITIAL AMPLIFIER GAIN

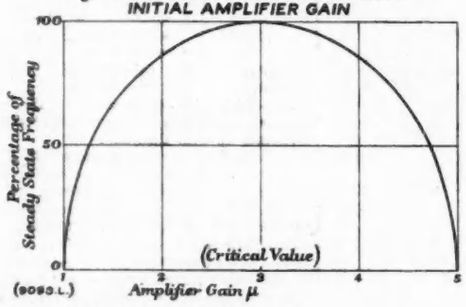



Fig. 15. SERIES-RESISTOR CIRCUIT

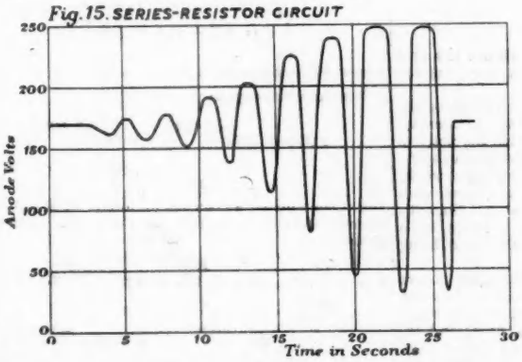
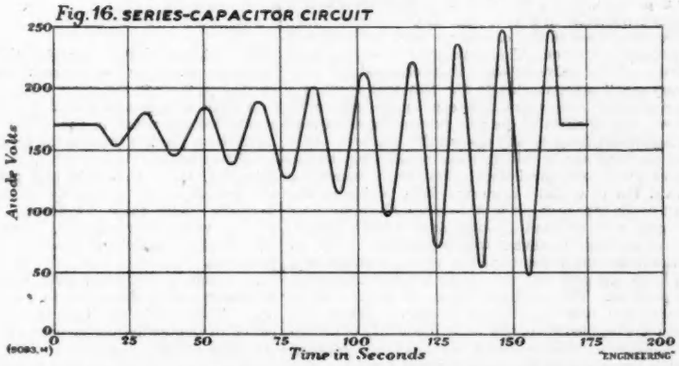



Fig. 16. SERIES-CAPACITOR CIRCUIT




build up and this is governed by the value of the effective $\mu$ of the stage. In approaching a stable amplitude of oscillation it is obvious that the effective $\mu$ must decrease towards some critical value as the amplitude of the oscillation increases, so that the exponential index finally becomes zero. This critical value is found from the equations to be given as:

$$\mu_{\text{critical}} = 29 + \frac{23R_2}{R} + \frac{4R_2^2}{R^2}.$$

The change in effective $\mu$ during the building-up process is made possible by the non-linearity of the valve characteristic, higher-order terms in the power series expansion for the characteristic becoming more important as the amplitude of the oscillation increases. This will also result in an increase in harmonic distortion as the amplitude increases. The expression for the frequency of the oscillation involves $\mu$ as a parameter, and since the effective $\mu$ is reduced to the critical value during the building-up process, there is a change of frequency during this process. Table I, on this page, gives theoretical values relating the value of the exponential index (and therefore the initial rate of build up) and the frequency with the initial effective $\mu$ of the stage.

These results have been confirmed by experimental observation at very low frequencies. For this type

TABLE I.

| Effective $\mu$. | Exponential Index. | Frequency as Percentage of Steady-State Frequency. |
|---|---|---|
| 20 | −0·156 | 117 |
| 29·22 | 0 | 100 |
| 35 | 0·0136 | 93 |
| 60 | 0·0874 | 75·1 |
| 120 | 0·0445 | 56·8 |
| 240 | 0·050 | 43·0 |

of oscillator the starting frequency is less than the steady-state frequency; also the magnitude of the frequency change during the building-up process depends on the difference between the initial and steady-state $\mu$ of the circuit, and hence bears a definite relation to the build-up time of the oscillation. The graph of the oscillation shows that the real root of the differential equation contributes a small direct-current transient slightly modifying the initial cycle of the oscillation.

An investigation of the feed-back network for the three-mesh series resistor type from the step function viewpoint does not give such useful information as in the previous case, and a more useful concept is to be found in the application of a rectangular pulse of voltage to the network. The application of a single voltage step merely results in the gradual charging of all three capacitors to this step, with the result that the output voltage is always uni-directional, rising gradually to the value of the step. The application of a rectangular pulse, however, shows that the output voltage, although uni-directional, may continue to rise even after the input voltage has reached zero. The theoretical solution is obtained by combining the results of applying two step functions of the same magnitude, the first positive and the second negative, separated by a short time interval. The result of this

is shown by the graph in Fig. 5, page 430, for a 100-volt rectangular pulse of 2 seconds duration applied to a network having values of R and C equal to one megohm and one microfarad, respectively.

Physically, this phenomenon depends on the fact that, under the influence of any applied voltage, the first and second capacitors will tend to charge more rapidly than the third capacitor. If the applied voltage is subsequently removed there will then be an unequal distribution of charge among the capacitors which will tend to equalise itself. In so doing the discharge of the first two capacitors will cause the third to acquire a little more charge before it ultimately commences to discharge. The values of all three capacitor voltages throughout the process are shown by the graphs.

The complete circuit is shown in Fig. 6, page 430. It will be noted that a backing-off battery is employed in place of a coupling condenser in order to simplify the investigation. An oscillatory solution is again obtained, provided that the effective $\mu$ is greater than the value 1·11. This time the differential equation is:

$$\left[p^3T^3\left(\frac{R_0+R}{R}\right)+p^2T^2\left[1+\frac{4\,(R_0+R)}{R}\right]+3pT\left(\frac{R_0+2R}{R}\right)+(\mu+1)\right]v=0$$

and the roots of the auxiliary equation for $\mu = 35$ and $\frac{R_0+R}{R} \doteq 1$ are:

$$\alpha=-\frac{5\cdot267}{T}\,;\qquad \beta=\frac{1}{T}(+0\cdot133+j\,2\cdot5463)\,;$$

$$\gamma=\frac{1}{T}(+0\cdot133-j\,2\cdot5463).$$

The Heaviside expansion theorem gives the complete expression for the grid voltage, on the application of a step $E_1'$ in the anode circuit as:

$$V_g=E_1\left[\frac{1}{\mu+1}+\sum_{x=\alpha,\beta,\gamma}\frac{e^{xt}}{3x^2T^2+10x^2T^2+6xT}\,1\right]$$

where

$$E_1=E_1'\frac{R_A}{R_A+R_L},$$

and substituting the values of $\alpha$, $\beta$, $\gamma$ in this expression gives the final solution for the grid voltage (with $R = 1\,M\Omega$; $C = 1\,\mu F$) as:

$$V_g=E_1\left(0\cdot0278-0\cdot0052\,e^{-5\cdot267t}-0\cdot0262\,e^{0\cdot133t}\cos\left[2\cdot55t-20\text{ deg. }40\text{ min.}\right]\right).$$

The solution has been computed for the anode voltage, for a $\mu$ of 35, and a value of $E_1' = 100$ volts, and is shown graphically in Fig. 7, page 430.

The inception of the oscillation may be described physically as follows. The static position of the anode voltage of the valve is this time changed by only a very small amount, due to the fact that there is a direct-current connection between anode and grid, the controlling effect of the grid preventing the anode voltage from changing any appreciable amount. It is seen that the anode voltage rises immediately to the full value of the applied step, subsequently decreasing toward the new static position. This is due to the effect of the capacitor in the grid circuit which prevents the grid voltage from making any sudden change. The capacitors, however, will commence slowly to charge under the influence of the applied voltage step, and hence the grid-cathode voltage will become gradually positive. This results in the anode voltage falling towards the new equilibrium position. When this position is reached there will be an inequality of charge distribution in the feed-back network corresponding to that produced by the application of a pulse. The first two capacitors will then relinquish some of their charge to the grid capacitor and the grid voltage will thus continue to go positive, swinging the valve past its static point. The input voltage to the network will then be falling below the original level on which the positive step was applied, and thus will tend to charge the condensers in the reverse direction. Ultimately, therefore, a point must be reached where the falling anode voltage due to the rising grid potential will be halted, due to the falling voltage being applied to the network. This will be the turnover point of the oscillation.

Again, there is a real root in the differential equation which gives a small direct-current transient slightly modifying the first cycle of the oscillation. As in the previous case, $\mu$ diminishes during the build-up process. In this case, however, a decrease of $\mu$ is found to reduce the frequency of oscillation, and thus the starting frequency of the oscillation will be higher than the steady-state frequency. This phenomenon was confirmed by experimental investigation.

The two-mesh zero phase shift type circuit is usually employed with a two-valve maintaining amplifier operated with a large amount of negative feed-back, reducing the overall gain to 3, the critical value for the steady-state oscillation. The circuit employed for experimental investigation is as shown in Fig. 8, page 430. Use was again made of a backing-off battery between the two valves so that the investigation could be simplified and the circuit operated at very low frequencies. For the purpose of analysis the circuit can be simplified to that of Fig. 9, page 430.

Analysis of this circuit yields a second-order differential equation for the grid voltage having a pair of complex conjugate roots (*i.e.*, a true oscillatory solution) for a range of values of effective $\mu$ between 1 and 5. The equation is:

$$\left(p^2T^2+(3-\mu)\,pT+1\right)v=0.$$

The roots of the auxiliary equation have been calculated for several values of effective $\mu$ between 3 and 6. Heaviside's expansion theorem gives the transient solution for the grid voltage of $V_1$ on the application of a step of voltage in the anode circuit of $V_2$ of magnitude $E_1'$ as:

$$V_g=E_1\sum_{x=\beta,\gamma}\frac{e^{xt}}{2xT+(3-\mu)}\,1$$

where

$$E_1=E_1'\frac{R_A}{R_A+R_L}.$$

The anode voltage of $V_2$, grid voltage of $V_1$ and the voltage across the series capacitor have been computed for values of $\mu$ equal to 3, 4 and 6, and a value of $E_1 = 1$ volt. The resulting graphs are shown in Figs. 10 to 13, pages 430 and 431.

In this case there is again a change in the static anode potential of $V_2$. It is seen that when this new position is reached at the end of the first half cycle, there is some residual charge on the series capacitor.

*Fig. 17.*

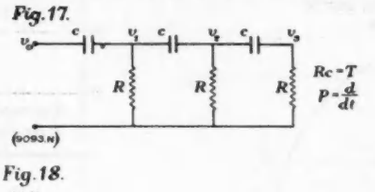
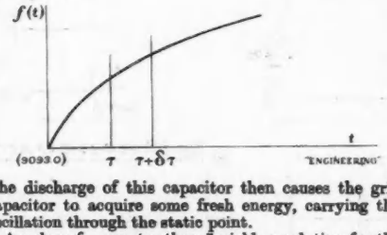



*Fig. 18.*




The discharge of this capacitor then causes the grid capacitor to acquire some fresh energy, carrying the oscillation through the static point.

A value of $\mu$ greater than 5 yields a solution for the anode voltage which is the sum of two exponential terms with positive indices, the term with the positive coefficient having the larger index. The graph shows, therefore, that the anode and grid voltages would theoretically rise to infinity if the oscillator were operated under these conditions. The non-linearity of the valve characteristic, however, results in a relaxation oscillation of a non-sinusoidal type being produced.

A change in frequency with build-up again occurs in this type of oscillator, due to the change in the value of $\mu$. This may be seen both from the difference in the period of the oscillations shown in Figs. 10, 11 and 12, and from Fig. 14, pages 430 and 431, which relates the starting frequency with the initial value of $\mu$. For $\mu$ less than 3 the circuit will, of course, only give a damped oscillation on the application of a voltage step. It is seen that the starting frequency will be less than the steady-state frequency.

Confirmation of the theoretical analysis on the above types of oscillator was made by constructing oscillators to work at very low frequencies, *e.g.*, a period of about 18 seconds, and to operate a pen-recording milliameter. Steps of voltage of various magnitudes were introduced into the anode circuit simultaneously with the removal of a "short" from the grid circuit. It was seen that the build-up time was dependent on the magnitude of the injected pulse, and on the effective gain of the stage, as was to be expected from the mathematical considerations. The direction of the change of frequency during the building-up process was also confirmed. A comparison between the two single-valve oscillators when operated under identical conditions, *i.e.*, over approximately the same operating range of the valve characteristic, showed the series-capacitor circuit to be superior from the viewpoint of harmonic distortion. The graphs of anode voltage obtained experimentally for the two circuits are shown in Figs. 15 and 16, page 431. In the series-capacitor circuit the harmonics generated in the anode circuit due to the non-linearity of the valve characteristic are transmitted to the grid with negligible shift in phase and small attenuation. They therefore tend to annul their generation in the anode circuit. In the series-resistor circuit, however, the phase shift for the harmonic approaches 270 deg. and their attenuation is appreciable, *i.e.*, the phase and magnitude of the harmonic voltages arriving at the grid does not contribute to reducing the harmonic distortion.

In conclusion, it may be observed that the change of frequency during build-up is of practical interest in the design of keyed RC oscillators for telegraphy purposes. Some compromise must be made between the length of build-up time as determined by the speed of keying, and the degree of "chirping" of the note that can be tolerated due to the change in frequency at fast rates of build up.

*Appendix* (i).—Evaluation of the transient solution of the series-capacitor network using the Heaviside expansion theorem:

In the network of Fig. 17, $v_3$ can be found in terms of $v_0$, *i.e.*,

$$V_3=\frac{p^3T^3V_0}{p^3T^3+6p^2T^2+5pT+1}.$$

Let

$$p^3T^3=f_1(p)\,;\quad p^3T^3+6p^2T^2+5pT+1=f_2(p),$$

and let the roots of $f_2(p)$ be $\alpha$, $\beta$, $\gamma$. If $v_0$ is a Heaviside step function of magnitude $E_1$, then $v_3$, by the expansion theorem is given by:

$$V_3=E_1\left[\frac{f_1(0)}{f_2(0)}+\sum_{x=\alpha,\beta,\gamma}\frac{f_1(x)\,e^{xt}}{x\,f_2'(x)}\right]1$$

$$=E_1\sum_{x=\alpha,\beta,\gamma}\frac{x^3T^3\,e^{xt}}{3x^2T^2+12xT^2+5T}\,1$$

$$=E_1\sum_{x=\alpha,\beta,\gamma}\frac{x^2T^2\,e^{xt}}{3x^2T^2+12xT+5}\,1$$

Analysis of the other circuits may be similarly treated.

*Appendix* (ii).—Evaluation of the response of a network to a constant rate of rise of voltage using the Duhamel integral theorem:

If the applied wave is represented by $f(t)$, Fig. 18, and the response of the network to a Heaviside unit step applied at $t = 0$ is $g(t)$, then between the time interval $\tau$ and $(\tau + \delta\tau)$ the applied wave increases by an amount $f'(t)\,\delta\tau$. This is equivalent in the limit as $\delta\tau \to 0$ to a Heaviside step of magnitude $f'(\tau)\,\delta\tau$.

At a subsequent time $t$, the response of the network to this step is given by $g(t-\tau)f'(\tau)\,\delta\tau$. Hence the total response to the function at a time $t$ is given by:

$$\int_0^t f'(\tau)\,g(t-\tau)\,d\tau+f(0)\,g(t)$$

where $f(0)$ is the value of $f(t)$ at $t = 0$.

For the series-capacitor network:

$$g(t)=1\cdot217e^{-5\cdot049\frac{t}{T}}-0\cdot28e^{-0\cdot6432\frac{t}{T}}+0\cdot05964e^{-0\cdot3079\frac{t}{T}}$$

and if the applied wave rises uniformly at E volts per second, starting from zero at $t = 0$, the output is given by:

$$V=E\int_0^t g(t-\tau)\,d\tau=\int_0^t\left[-0\cdot242e^{-5\cdot049\frac{t-\tau}{T}}+0\cdot4355e^{-0\cdot6432\frac{t-\tau}{T}}-0\cdot1935e^{-0\cdot3079\frac{t-\tau}{T}}\right]$$

$$=-0\cdot242\,e^{-5\cdot049\frac{t}{T}}+0\cdot4355\,e^{-0\cdot6432\frac{t}{T}}-0\cdot1935e^{-0\cdot3079\frac{t}{T}}$$

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INSTITUTE OF MARINE ENGINEERS.—The next examinations for the admission of graduates and associate members of the Institute of Marine Engineers will be held on Monday, May 24, to Monday, May 31, 1948. Syllabuses and particulars of exempting qualifications are obtainable from the secretary, The Institute of Marine Engineers, 85, Minories, London, E.C.3.

RETURN TO SERVICE OF R.M.S. "STIRLING CASTLE."—The Union-Castle liner Stirling Castle has been refitted by the builders, Messrs. Harland and Wolff, Limited, Belfast, and has now sailed on her first post-war voyage to South Africa. The Stirling Castle is the fifth of the Union-Castle fleet to return to her peace-time duties, having been employed as a troopship during the war.